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FAO
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158

Fighting sand encroachment

Lessons from Mauritania

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Cover photo:
Mechanical dune stabilization: installing plant matter
M. Ould Mohamed

Fighting sand encroachment

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PAPER

158

by
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with the collaboration of
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Ministry of the Environment and Sustainable Development of Mauritania

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Foreword

Mauritania is one of the Sahelian countries most severely affected by the repeated periods of drought that have been occurring since the end of the 1960s. Desertification control has always been a national priority and a central concern of successive governments, taking the practical form of various development plans and programmes over the past four decades.

After ratification of the United Nations Convention to Combat Desertification (UNCCD), in June 2001 Mauritania formulated a National Action Plan to Combat Desertification (PAN-LCD), adopting an integrated, participatory approach. As in other countries in the Sahelian region, constantly increasing desertification is due to various natural, human, juridical and socio-economic factors, which combine to cause degradation of soil, forest resources and biodiversity.

Implementation of the PAN-LCD is based on various fundamental principals, including:

- adoption of an integrated approach covering physical, biological, institutional and socio-economic aspects;
- integration of poverty reduction into desertification control programmes;
- coordination of activities to be carried out under the PAN-LCD with those of other United Nations framework conventions, such as the Convention on Climate Change and the Convention on Biological Diversity;
- more closely targeted international assistance in order to respond better to local needs in the framework of partnership agreements;
- the participatory approach, with close collaboration of grassroots communities, especially local government and non-governmental organizations;
- encouragement of scientific research and the use of its results in the rehabilitation of degraded land and the improvement of agrosilvopastoral production.

The present publication has been produced within the framework of FAO support for the Mauritanian Government's efforts to combat desertification, and reflects results and lessons learned during implementation of the Support for the Rehabilitation and Extension of the Nouakchott Green Belt Project with financing from the Walloon Region and the support of Prince Laurent of Belgium.

J.A. Prado
Director, Forest Assessment, Management and Conservation Division
FAO Forestry Department

A prologue from Prince Laurent of Belgium

What picture can we give our children today of our relationships between north and south, which are so often tarnished by a spirit of imperialism and a poor knowledge and understanding of other cultures that too often are foreign to us? The spectacular progress of science and knowledge in recent decades should have allowed us to know each other better, thus enabling us to join together to envisage a more sustainable outlook for the future. The foundations of our western civilization and knowledge come from other continents, including of course Africa.

Today, we sometimes have to realize that when we withdraw into ourselves this gives rise to relationships based on force and thus to immense frustration. However, if we take the time to reflect on nature, it teaches us that the party we believe to be the strongest is not always the one that wins out over the weakest.

I was deeply imbued with the knowledge, love and passion for forests of my spiritual father, Raymond Antoine, Professor Emeritus of Forest Engineering at the Catholic University of Louvain, who is always present in my thoughts. I also love to stroll through the works of my friend Jean-Marie Pelt, Professor Emeritus of Plant Biology and Pharmacology at the University of Metz, for whom I have great admiration.

Professor Pelt is particularly interested in the relationships of attraction and repulsion among plants and animals in a single ecosystem. Based on his observations, he teaches us about the relations between the Douglas fir and the birch. These two trees exchange carbonaceous sugars through almost invisible mycelial filaments. As the Douglas fir has needle-shaped leaves throughout the year, which ensure its photosynthetic activity, it is able to pass on carbonaceous sugars to a leafless fellow tree of another species. During its vegetative period, the birch provides the same service to the Douglas fir. What a splendid symbiosis we see in the plant world with the fragile-looking fungus, which brings the tree the water and mineral salts it needs, and the tree, which in return offers the organic nutrients the fungus needs for its survival. And of course there is the orchid species with no chlorophyll whose development and survival is vitally linked to the beech tree through similar mycelia.

All this shows us how much more attention we should pay to ecology and the environment. I am convinced that many of our societies' problems could find solutions in the mechanisms underpinning nature.

The relationship between trees, development and the maintenance of a sustainable agriculture is not yet sufficiently well established in our consciousness. It has been shown in Europe that forest and agricultural monocropping systems produce much less timber and food than does a harmonious combination of these two elements, as found in agroforestry. It is still too little known that trees generate soil and thus allow the development of sustainable agriculture, and also that they prevent erosion and conserve water.

However, in the greater Maghreb region, where pastoralism is the predominant system, silviculture provides the guarantee of sustainable agriculture. If we are to attain this ambitious objective, we have to establish an agrosilvopastoral centre within the region to facilitate scientific exchanges between north and south and among the countries of the region.

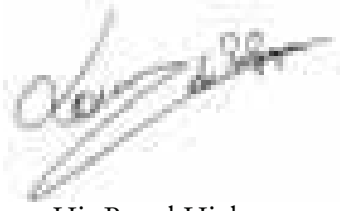
This undeniably leads us to realize that the very concept of the environment is the source of a better understanding of our various cultures, and will hence generate peace.

Without a doubt, the two main challenges facing our planet will be, on the one hand, the development of renewable energies that are accessible to one and all and, on the other, the reforestation of forest land.

I was delighted that the project I had presented to His Excellency Maaouiya Ould Sid'Agmed Taya, then President of Mauritania, was given major priority both by him and his country, and that he entrusted me with seeing it through to completion.

The present President, His Excellency Mohamed Ould Abdel Aziz, has assured me of his support and complete collaboration in maintaining the work carried out.

I would thank the partners who have enabled me to achieve my objectives: FAO and the Walloon Region of Belgium, together with the Mauritanian Ministry of the Environment and Sustainable Development.



His Royal Highness,
Prince Laurent of Belgium

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The author is keen to thank a whole series of people without whom the Support for the Rehabilitation and Extension of the Nouakchott Green Belt Project and the present document would have been impossible:

- Prince Laurent of Belgium, President of the Royal Institute for Sustainable Natural Resource Management and the Promotion of Clean Technology, who must be credited with the initiative for this project, and his adviser, James Lohest;
- the ministers of the Walloon Region of Belgium in office during the course of the project: Marie-Dominique Simonet, William Ancion, Michel Forêt, José Happart, Benoît and Guy Lutgen, Jean-Claude Van Cauwenberg and Rudy Demotte;
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- Philippe Suinen, General Administrator of Wallonie Bruxelles International–Multilatéral Mondial (WBI), together with Philippe Cantraine and Daniel Sotiaux, WBI Directors, and Laurence Degoudenne, WBI Desk Chief;
- the Operational General Directorate for Agriculture, Natural Resources and the Environment, Department of Nature and Forests, especially Philippe Blerot, Inspector General, and Guy Coster, Officer;
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- André Matton of the FAO Liaison Office in Brussels for the European Union and Belgium;
- the World Food Programme (WFP) representatives in Mauritania and the WFP Officer in Charge of the Environment Programme, Boubacar Konté;
- Raymond Antoine, adviser to the Walloon Region, who contributed considerably to the success of the project with his professional experience and many elements of advice offered during technical and evaluation missions;
- Jonathan Shadid, Director of the national non-governmental organization Communication in the Service of Development (NEDWA) in Mauritania.

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Abbreviations, acronyms and terminology

AFESD	Arab Fund for Economic and Social Development
CILSS	Permanent Inter-State Committee for Drought Control in the Sahel
DANIDA	Danish International Development Agency
FAO	Food and Agriculture Organization of the United Nations
GTZ	German Agency for Technical Cooperation
IFAD	International Fund for Agricultural Development
LWF	Lutheran World Federation
moughataa	prefecture
NGO	non-governmental organization
PANE	National Action Plan for the Environment
PAN-LCD	National Action Plan to Combat Desertification, Mauritania
PDLCD	Desertification Control Master Plan
PLEMVASP	Sand Encroachment Control and Agrosilvopastoral Development Project
PMLCD	Multisectoral Desertification Control Programme
UM	ouguiya (Mauritanian currency)
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNSO	United Nations Sudano-Sahelian Office
US$	United States dollar
WBI	Wallonie-Bruxelles International
WFP	World Food Programme
wilaya	administrative district

1. Introduction

The United Nations Convention to Combat Desertification (UNCCD), adopted in Paris on 17 June 1994, includes the following definitions:

- "desertification" means land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities;
- "combating desertification" includes activities which are part of the integrated development of land in arid, semi-arid and dry subhumid areas for sustainable development which are aimed at:
  - prevention and/or reduction of land degradation;
  - rehabilitation of partly degraded land;
  - reclamation of desertified land.

Mauritania is one of the Sahelian countries most severely affected by the periods of drought that have been occurring since 1968. The resulting desertification is exacerbated by human activities, which have compounded climatic factors, with direct consequences for an already precarious situation – bringing about degradation of the environment and the general socio-economic conditions of the country, and the progressive impoverishment of a population that is 70 percent rural.

The main effect of desertification has been a reduction in the amount of arable land, grazing land, forests and water resources. Various studies show that mobile sand dunes today cover two-thirds of the country's land area.

The devastating effects of desertification and drought on agricultural productivity and yields have resulted in:

- endangerment of rural inhabitants' food security and standard of living;
- large-scale movements of people toward major urban centres;

Sand encroachment threatening the town of Nouakchott

- reduced water supplies for human and livestock needs;
- substantial economic losses.

In view of the extent of the phenomenon, Mauritania, like many other countries affected by drought and desertification, has expressed a firm political will to combat this scourge.

It was in this context that the Sahel Club and the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS) were established. In 1980, CILSS designed a drought control and development strategy for the countries of the Sahel, with the two main objectives of bringing about food self-sufficiency and environmental balance. However, implementation of the strategy did not have the anticipated results because of the complexity of the desertification problem. Recognizing this failure, the Mauritanian Government decided to incorporate desertification control into an overall process of sustainable development of the country, encompassing technical, socio-economic, juridical and institutional factors, a decision leading to:

- formulation of a Desertification Control Master Plan (PDLCD);
- formulation of a Multisectoral Desertification Control Programme (PMLCD);
- formulation of a National Action Plan to Combat Desertification (PAN-LCD);
- formulation of a National Action Plan for the Environment (PANE).

Within this framework, national-level programmes and projects have been implemented with the support of development partners in order to foster conservation and agrosilvopastoral development and combat sand encroachment. These programmes and projects include:

- the Nouakchott Green Belt Project, financed by the Lutheran World Federation (LWF);
- the Sand Dune Stabilization and Fixation Project, financed by the United Nations Development Programme (UNDP), the Danish International Development Agency (DANIDA) and the United Nations Sudano-Sahelian Office (UNSO);
- the Sand Encroachment Control and Agrosilvopastoral Development Project (PLEMVASP), also financed by UNDP, DANIDA and UNSO;
- the Oasis Development Project, financed by the International Fund for Agricultural Development (IFAD) and the Arab Fund for Economic and Social Development (AFESD);
- the Kaedi Green Belt Project, financed by the European Union;
- the Integrated Natural Resource Management in East Mauritania Project, financed by the German Agency for Technical Cooperation (GTZ);
- the Support for the Rehabilitation and Extension of the Nouakchott Green Belt Project, with financing from the Walloon Region of Belgium and the support of Prince Laurent of Belgium.

2. Understanding sand encroachment

Sand encroachment is said to take place when grains of sand are carried by winds and collect on the coast, along water courses and on cultivated or uncultivated land.

As the accumulations of sand (dunes) move, they bury villages, roads, oases, crops, market gardens, irrigation channels and dams, thus causing major material and socio-economic damage. Desertification control programmes must then be implemented in order to counter this very serious situation.

Before designing such programmes, information is needed about the factors and processes fostering the formation and movement of sand masses, i.e. wind and soil.

WIND EROSION

The main causes of wind erosion are:

- a violent wind blowing over large areas;
- stunted or sparse vegetation;
- a degraded soil that is mobile, bare and dry.

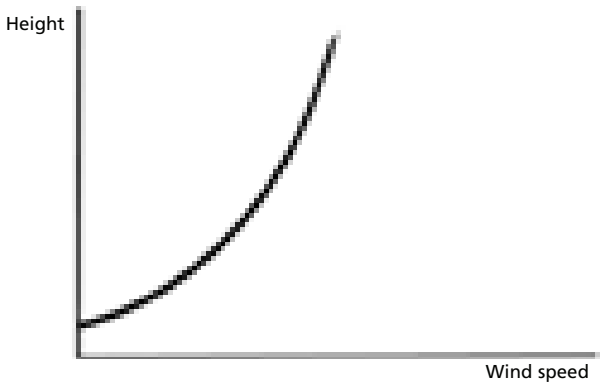
Violence of wind

The first factor affecting the displacement of soil particles is the direction, speed and duration of the wind. When a wind blows predominantly from one direction, it is known as a prevailing wind. Wind speed is zero at ground level, but increases in force the higher it is from the surface of the ground, its speed increasing as the logarithm of height (Figure 1).

A wind cannot lift sand particles off the ground until its speed at 30 cm above ground level, measured with an anemometer, is at least 6 m per second. Wind speed is an essential factor, for it determines the force of sand removal. The greater is the speed, the greater the carrying capacity.

The second factor is the size and density of sand particles. Particles with a diameter of about 0.1 mm are the first to be removed, whereas a violent wind is needed to remove larger particles.

FIGURE 1
Wind speed in function of altitude



Curve S = f(h), according to Henin

Source: Henin *et al.*, 1960

The nature of the movement of particles varies depending on their size (Figure 2):

- The largest particles roll or slide along the ground in a mechanism known as reptation or creep. The grains of sand that move in this way are between 0.5 and 2 mm in diameter depending on their density and the wind speed. When they start to travel more slowly because of the braking effect of the sand mass, the saltation mechanism becomes possible.
- Medium-sized (0.5 to 1.1 mm diameter) particles move forward in successive bounds, in a mechanism known as saltation. After leaping into the air, these particles fall back to the ground under the effect of weight; 90 percent of them reach a height of no more than 30 cm, moving on average between 0.5 and 1 m along the ground. The saltation mechanism is of vital importance in triggering wind erosion.
- Very fine particles, with a diameter of 5 microns or less, are shot into the air in the form of dust by the impact of larger grains. These particles then remain suspended and may be carried a long way in the form of a dust cloud, which often reaches an altitude of 3 000 to 4 000 m.

General mechanisms involved

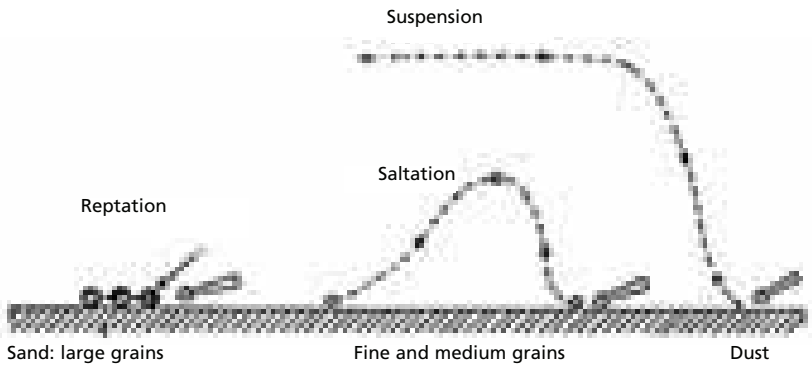
Particles in movement are the site of various interactions, the main ones being the avalanche effect, sorting and corrosion.

The avalanche effect is the result of saltation. As the grains of sand fall back, they cause the displacement of a larger quantity of particles, so that the more intense the saltation process caused by the wind, the greater the number of particles set in motion, until a maximum or saturation point is reached, where the quantity lost is equal to the quantity gained at any given moment. The distance needed to reach this saturation point will depend on the sensitivity of a soil to erosion: on a very fragile soil, it can occur over a distance of about 50 m, whereas it will require more than 1 000 m on a really cohesive soil.

The sorting mechanism concerns the wind's displacement of the finest and lightest particles, leaving behind the larger particles. This process gradually impoverishes the soil, since the organic matter made up of small light elements is the first to be removed.

Corrosion is the mechanical attack on the surface as the sand-laden wind blows over it. In arid regions, it is the aggravating cause of soil erosion and is seen in parallel streaks or the polishing of rocks.

FIGURE 2
Ways in which particles are carried by the wind



Source: Lemoine, 1996

State of vegetation

Vegetation preserves the cohesion of the surface layer of soil, retains particles, resists the avalanche effect and is the best protection against the negative effects of wind. This is why wind erosion is such a threat in arid and semi-arid regions where natural vegetation (whether woodland, bushland or grassland) is sparse, stunted or non-existent and where rainfall is low and irregular.

Moreover, unsustainable harvesting of such slow-growing stands leads to rapid degradation of the soil, which lacks protection and is therefore subject to the action of the wind.

Nature and state of soil

Wind erosion is the result of the wind's attacking the soil. Such erosion takes place if the soil has the following characteristics:

- mobile, dry and finely crushed (coarse-textured, rich in fine sand, poor in clay and organic matter);
- a uniform surface with no natural or artificial obstacles;
- sparse or non-existent plant cover;
- covering a sufficiently large area lying in the direction of the wind.

Soil that has been dried out over a long period is found especially in arid and semi-arid zones.

The soil's susceptibility to erosion can be exacerbated by poor farming practices (clearing of large areas), poor pastoral practices (overgrazing, with loosening and powdering of the soil) and unsustainable harvesting of forests, all of which make it extremely vulnerable to the action of the wind.

In Mauritania, soil is generally deep, fragile and predominantly sandy, and is for the most part located in zones with an annual rainfall of less than 100 mm.

ORIGIN OF SAND

When sand is carried by sea currents and accumulates along the shoreline in substantial quantities, it forms coastal dunes.

If it comes from the hinterland, it forms inland dunes, in which case the sand is either non-indigenous, coming from a considerable distance and having particles with a diameter of less than 0.05 mm, or indigenous, being of local origin and coming from the decomposition of mountain rocks (sandstone), the disaggregation of alluvial soil following the disappearance of plant cover, or from silt carried down by wadis following water erosion of their catchment basins.

For a long time, sand encroachment in Mauritania was considered a consequence of material carried from both near and far. However, according to Raunet (1985) and Khatteli (1989), non-indigenous material is insignificant compared with indigenous material.

EFFECTS OF WIND EROSION

On soil

The wind first carries off the finer parts of the soil – alluvium, fine sand and organic matter – thus weakening the soil structure. As the soil becomes sandier, it is more vulnerable to the wind and has a reduced water retention capacity. Its colour turns from grey to white and then to red as it is scoured. The terrain is gradually broken up by the creation of small mounds surrounding the woody and grassy vegetation as this degrades. The land gradually becomes unsuitable for cultivation.

On vegetation

The wind has both mechanical and physiological efforts on vegetation.

- ***Mechanical effects.*** The soil particles that are carried off collide with stalks and leaves with a force that abrades their tissue. In the zones from which the particles

are carried off, roots are uncovered and the vegetation risks being uprooted, while in zones where the particles are deposited the vegetation is steadily buried.

- ***Physiological effects.*** The wind increases evaporation and dries out plants, mainly in the dry season. The air's evaporating power is proportional to the square root of the wind speed. Moreover, the soil's water retention capacity is reduced, leading to water stress. The surrounding or moving mass of dry air tends to absorb humidity and exacerbate the water deficit – and this deficit is the main factor determining local vegetation, inasmuch as the latter has to adapt to the severe shortage of water.

WIND-BORNE ACCUMULATIONS

When the wind grows lighter, it loses its capacity to carry sand particles, which are then dropped. Forms of sandy accumulation vary widely, depending on landform, the nature of the soil on which they encroach, the presence or lack of vegetation, and the size of the grains of sand.

The main forms of accumulation found in Mauritania are wind veils, nebkas, barchans, linear dunes, sand ridges, pyramidal dunes, aklés and ergs.

Wind veils

Sand particles are carried over hard, flat, uniform surfaces, forming sandy veils of varying thicknesses, which are a constant threat to villages, roads, railways and irrigation channels. This type of wind accumulation is the source of the surface sand encroachment found almost everywhere in the country, which becomes particularly serious following clearing, forest fires and overgrazing.

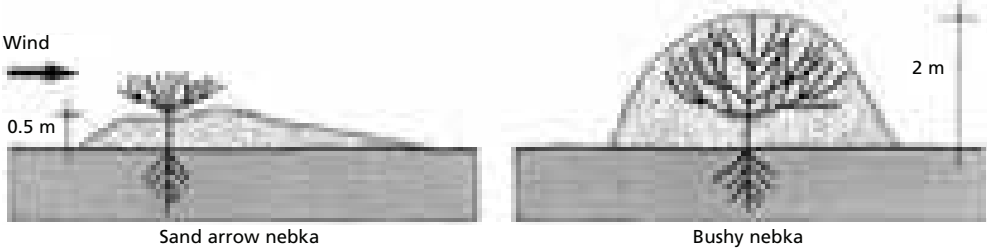
Nebka dunes

These accumulations are caused by the presence of a rock, plant or other obstacle in the path of sand particles in movement. There are two types of nebka: sand arrow nebkas, which are small ovoid dunes (50 cm in height, 150 cm in length and 40 cm in breadth) lying in the direction of the prevailing wind; and bushy nebkas, similar to sand arrow nebkas, but capable of reaching a height of 2 m and a length of 3 to 4 m (Figure 3).

Barchans

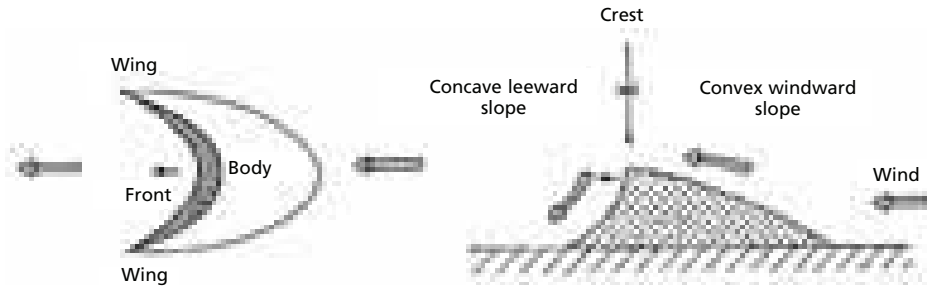
These are huge crescent-shaped dunes convex to the wind (Figure 4). There are several stages in their formation: they start as sandy shields, then turn into barchanic shields, then barchanic dihedrons, and finally full-scale barchans. Barchans tend not to remain isolated, but can join up and form complexes ranging from train-like successions of barchans to real dune massifs.

FIGURE 3
Nebkas



Source: FAO, 1988

FIGURE 4
Barchans



Source: Rochette, 1989

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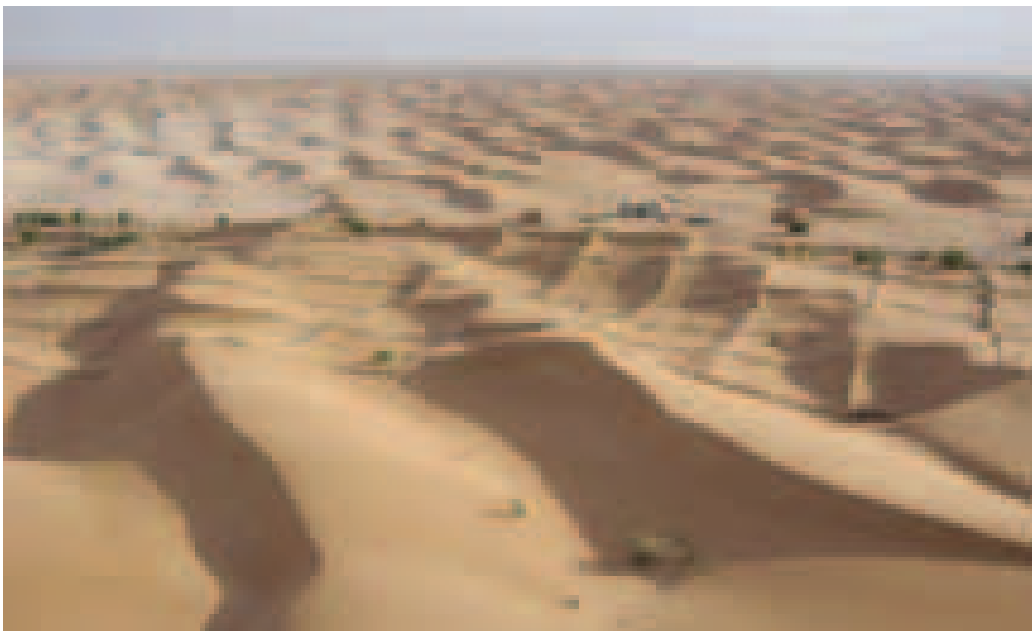
Isolated barchans



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Barchanic field or collection of barchans

Three conditions are needed for barchans to move: a constant wind from one direction, a large source of sand with grains of 0.12 to 0.25 mm in diameter, and a hard, flat surface. Inasmuch as barchans are unstable, mobile constructions that are constantly being remodelled by the wind, they can move several dozen metres per year.

Linear or sif dunes

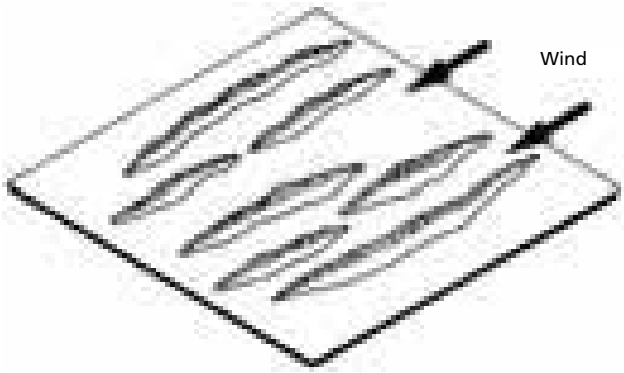
Linear dunes are elongated accumulations of sand, drawn out lengthwise like swords (*sif* in Arabic) (Figure 5). They are always eight to ten times longer than they are wide – on average 1 to 2 km long and 50 to 200 m wide. They sometimes gather together in formations that can reach 20 to 40 km in length, like those found alongside the Road of Hope.

This type of wind accumulation occurs in an arid environment with prevailing winds from two directions (northeast and southwest, for example) or a single prevailing wind with air flows that have been split up by irregularities in the terrain. These dunes lie obliquely to the average direction of the prevailing winds. The movement of a linear dune takes place through lengthening as new wind-borne sand is added.

Sand ridges

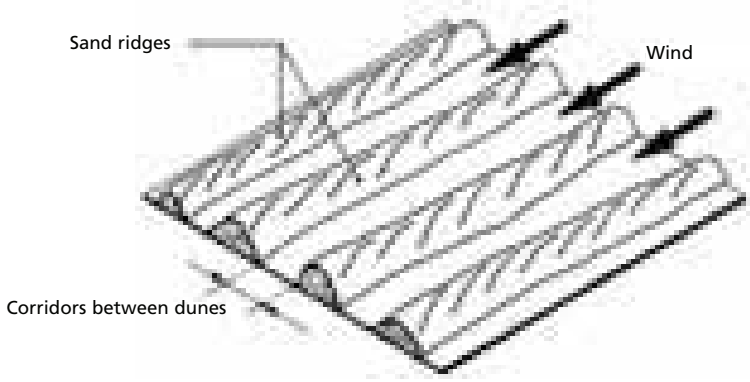
These ridges are large, broad sandy mounds, running lengthwise, side by side and separated by deflation corridors (Figure 6). They are fairly stable and do not move much. They lie in the direction of the prevailing winds, unlike linear dunes, which are

FIGURE 5
Linear dunes



Source: FAO, 1988

FIGURE 6
Sand ridges



Source: FAO, 1988

oblique to the average annual direction. Destabilization of these ridges is linked to the disappearance of woody and grassy cover. This type of formation can be seen on either side of the Road of Hope, with ridges running from northeast to southwest.

Pyramidal or ghourd dunes

Pyramidal dunes are hills of sand, often star-shaped, and can reach several hundred metres in height (Figure 7). They are the result of a convergence of various flows of wind and are basically stable and immobile. They thus become the source of sand that can give rise to barchans or linear dunes, as in the *wilayas* (administrative districts) of Tangant and Adrar.

Aklé dunes

This type of formation is found in the Inchiri and Adrar *wilayas*, and is a complex of overlapping dunes (Figure 8).

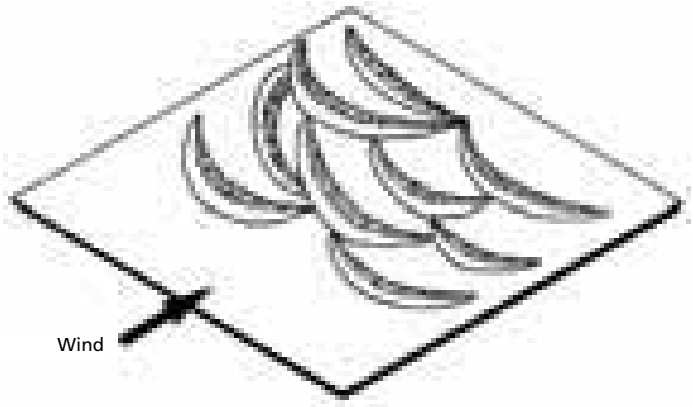
Ergs

Ergs are vast areas covered by dunes. This type of formation is very old (15 000 to 20 000 years) and stable. It presents no danger to urban areas, roads or crops.

FIGURE 7
Pyramidal dune

Source: FAO, 1988

FIGURE 8
Aklé dune



Source: FAO, 1988

IDENTIFICATION OF SANDED-OVER SITES

Field observation

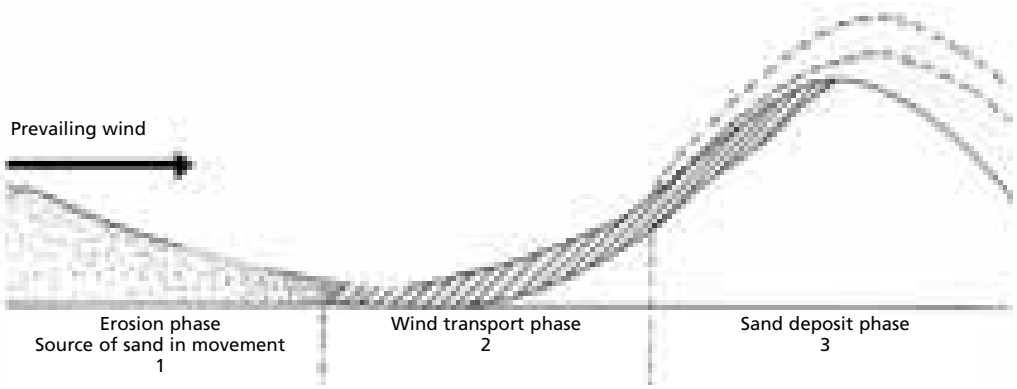
When a site is threatened by sand encroachment, the sources of sand, the transport zones and the accumulation sectors must be carefully identified (Figure 9).

The sources of sand may be local or mixed (indigenous or non-indigenous). Sand may also come from the degradation of plant cover, old dunes that have been reset in motion, or current matter coming from flood spreading, alluvial terraces or wadis. When the precise location and extent of sand sources have been properly identified, it is then possible to define the best stabilization techniques to be adopted.

Transport zones are the areas over which sand moves through saltation and rolling, leaving such traces of its passage as wind veils and nebkas. The direction of these traces indicates the direction in which sand is being moved toward deposit zones.

Accumulation sectors or deposit zones are major sand masses, such as barchans, linear dunes and sand ridges, which are a threat to villages, roads, market gardens and palm groves. These masses are turned into dune fronts when they encounter an obstacle in their path. The crests of these fronts mean that they constitute sand traps, which can reach a height of several metres and are capable of burying everything as they move forward. Accumulation sectors also constitute major masses of sandy matter that can be carried off by the wind and overrun other sites.

FIGURE 9
Dynamics of sand encroachment



Source: FAO, 1988

J. SHADID

Deflation and transport zone

Mapping of sanded-over zones

Sanded-over zones must be surveyed and mapped, with precise geographical coordinates. Studies will indicate the directions of sand encroachment, the location of sand deposit sectors and appropriate types of treatment.

In Mauritania, all the sanded-over sites in the various *wilayas* were surveyed and recorded in 1990 on a general map of the Multisectoral Desertification Control Programme (PMLCD). These data are available from the Directorate of Nature Protection of the Ministry of the Environment and Sustainable Development.

TYPES OF TREATMENT

With a view to fixing mobile dunes, it is necessary to study the composition and characteristics of the sand, the strength, frequency and direction of the wind, the quantity, duration and frequency of rainfall, and the existence or lack of natural plant cover on the dunes.

The fundamental principle of dune fixation is that of preventing sand from moving during a long enough period to allow natural or planted vegetation to become established. If sand encroachment is to be controlled, saltation must be reduced, either by stabilizing the soil or by reducing the wind speed gradient close to the surface of the ground. Wind speed can also be used in techniques to manage sand and dune masses, for when the wind moves fast it removes sand, thus clearing sanded-over sites. On the other hand, when its speed decreases, it drops sand. On the basis of these general principles, two types of fixation can be distinguished.

Primary fixation entails either the mechanical stabilization of sand masses by slowing their speed and movement or preventing the formation of such masses through:

- installation of palisades or fences and wattling perpendicular to the prevailing wind;
- spreading of material that can cover the soil in a uniform manner (mulching);
- shaping of the obstacle in order to maintain or increase the wind speed, a technique that increases the sand mobilization and transport capacity.

Definitive or biological fixation is done by installing and protecting a permanent woody and/or grassy plant cover (sod seeding or direct sowing, fencing off, permanent posting of guards).

3. Sand dune fixation techniques

PRIMARY FIXATION

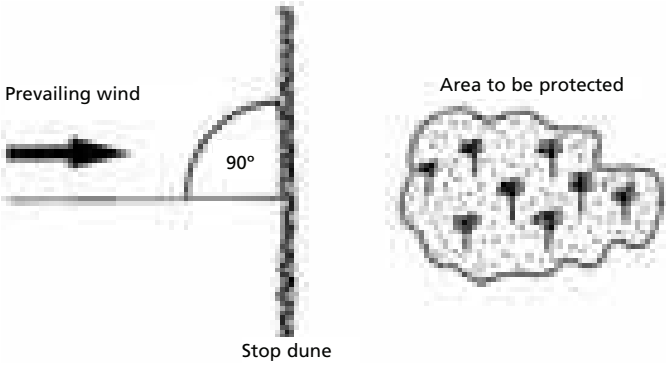
Mechanical dune stabilization

The initial phase in combating sand encroachment consists of halting or slowing the movement of sand by erecting fences 1 to 1.5 m high to cause a buildup of sand, leading to the formation of an artificial dune. The mechanical explanation for this process is that the fence slows down the flow of air, and this slowing down causes the air to release its load at this point. Two types of artificial dune are distinguished, depending on the positioning of the fence in relation to the prevailing wind.

Stop or check dunes, the most common way of preventing sand from advancing, are formed by setting up fences directly across the path of the prevailing wind (Figure 10). If winds also come from directions other than that of the prevailing wind, the installation incorporates a checkerboard or grid of stop lines, creating squares or diamonds between two successive fences. The nature and installation technique of these lines are similar to those of fences, with each element in the grid acting as a fence beyond which sand is deposited. The spaces within the grid are gradually filled up as they trap more sand.

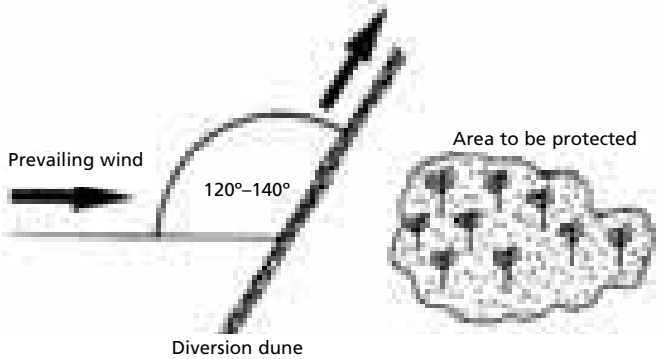
Deflection or diversion dunes, which deflect advancing sand in a direction other than that of the prevailing wind, are formed by setting up fences at an angle of 120 to 140 degrees to the average direction of the prevailing wind (Figure 11). However, this

FIGURE 10
Stop or check dune



Source: FAO, 1988

FIGURE 11
Deflection or diversion dune



Source: FAO, 1988

arrangement is not widely used, inasmuch as the diverted sand may invade other areas – settlements, crops and various types of infrastructure – even at a considerable distance from the zone that is the object of the stabilization work.

The fences may be woven (more expensive) or unwoven, and are usually made of branches and twigs from mature forest stands of suitable species, such as natural stands of *Prosopis juliflora*, *Balanites aegyptiaca* and various acacias, but also of palm fronds or *Leptadenia pyrotechnica* or euphorbia stalks. This material must be rationally extracted so as not to endanger the sustainability of existing stands. Straw from millet, sorghum, rice and other natural leafy vegetation such as *Panicum turgidum* may also be used.

After the site has been marked out with stakes, the plant matter is set in a trench to form hedges. If it is hard to obtain plant matter, the use of perforated sheets of fibrocement or synthetic latticing is recommended.

If a fence is to work effectively, it must have a 30 to 40 percent permeability to the wind, so that it curbs wind speed and causes a buildup of sand without causing wind turbulence in the lee, and be no more than 1.2 m high, inasmuch as 95 percent of wind-borne sand is found in the first 30 cm above the ground (Figure 12).

The fences and the interior grid must be regularly maintained and raised when the sand comes to 10 or 15 cm from their upper edge, so that they keep working effectively. Any breach in these structures can quickly set large amounts of sand in motion, again cancelling out their effectiveness. The fences are repeatedly raised until the artificial dune attains a balanced shape and thus becomes stable and fixed.

The size of the mesh in the grid is determined by the intensity of the winds and the slopes and shapes of the dune. The more complex the dune model, the denser the grid (fences and interior wattling), which can range from 600 to 1 200 linear metres per hectare.

Permanent posting of guards optimizes maintenance work by preventing any intrusion by livestock (camels, sheep, goats and donkeys), for which corridors are allocated. The guards can also make those living on the edges of protected areas aware of the need to respect and preserve the installations, which will quickly ensure the protection of their infrastructure (dwellings, mosques, crops, market gardens, roads, etc.) against sanding over and help protect their environment.

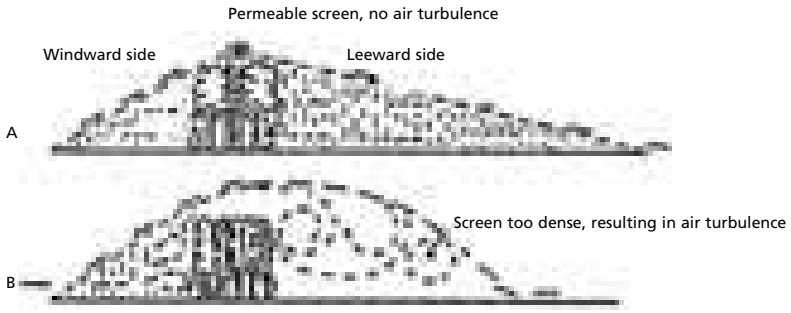
Mulch or protective screen

The mulch technique consists of covering the dune uniformly with a natural or artificial protective screen to prevent saltation and is adopted especially on flat or reasonably even surfaces. The mulch can be made of various materials, such as straw, branches, stalks, plastic film or acrylic fibre and mesh.

M. OULD MOHAMED

Grid made of extruded polystyrene

FIGURE 12
Air flow above a permeable screen (A) and an impermeable screen (B)



Source: Centre Technique Forestier Tropical, 1989

For the sake of completeness, it should be mentioned that mineral oils (asphalt, heavy oil and crude oil) can also be used to fix moving sand. Although this procedure is expensive and tends to lack long-term effectiveness, it is adopted particularly in oil-producing countries. The Islamic Republic of Iran, for example, has carried out major dune fixation work using this procedure, associated mainly with tamarisk plantations.

Aerodynamic method

This method aims at using the wind's speed and carrying capacity, either (i) by making it remove unwanted sand deposits through procedures that increase its speed in contact with them (such as orienting streets in some Sahelian towns parallel to the prevailing wind, or placing stones at a certain distance from one another along the crest of the dune to be removed) and ensuring that it meets no obstacles and thus carries the deposits far away; or (ii) by shaping obstacles in the path of the sand-laden wind, so that they have an aerodynamic effect on the air flow, causing a compression that increases its speed instead of reducing it, but without creating any turbulence, a process that helps buildups of sand to be carried off. This latter principle of accelerating or maintaining wind speed stabilizes or increases its carrying capacity and therefore its drag power. Thus it literally sweeps away the sand that is to be removed. This method is the opposite of that of slowing down the wind through the use of fences. The most striking example of its use is the transverse streamlining of a road and a strip on either side of it. Streamlining must be applied to all obstacles in the path of the wind – piles of sand, stones, vegetation, etc. – and is carried out on both sides of the road, making an average total width of 25 m. In Mauritania, the method has been successfully applied to certain sections of the Road of Hope, although these sections must be monitored and the streamlining maintained if the effect is to be lasting.

BIOLOGICAL FIXATION

After dunes have been mechanically stabilized, they can then be permanently fixed by planting trees and perennial vegetation.

Dunes present a difficult environment for the establishment and growth of all plant species, so that any planting must be done with species that can adapt to the environment and the depth of residual moisture in underlying strata. Bare sand dunes have the special feature of conserving part of their infiltrated water for fairly long periods, inasmuch as they have a high light reflection coefficient (albedo) and very low heat conduction rate, so that they are little affected by major variations in temperature and are severely heated to a depth of only 1 m. Moreover, sand allows only

a weak capillary rise of moisture. The top 20 to 30 cm of the dune act as a protective screen, thus reducing the loss of the moisture in lower levels that is essential for the establishment and growth of the species planted.

Choice of woody and grassy species

The choice of species depends on climatic and ecological conditions. Species selected for planting should meet the following criteria:

- the capacity to grow in a nutrient-poor environment subject to major variations between daytime and night-time temperatures;
- the existence of a tap-root system that can quickly reach the residual soil moisture, thus offsetting the effects of drought;
- resistance to strong, hot, dry winds and their abrasive action on leaves and stems;
- rapid growth and the ability to regenerate easily;
- the capacity to improve the dune soil – as is intended with the introduction of nitrogen-fixing species (legumes).

Some species adapt to various parts of dunes, others to the areas between dunes. After many trials, the main species selected for planting in Mauritania are as follows.

- ***On inland dunes.*** *Prosopis juliflora*, the only woody species that has so far had good, sustainable results on this type of soil, and *Aristida pungens* are planted on very mobile strip dunes. *Leptadenia pyrotechnica, Aristida pungens* and *Panicum turgidum* are planted in deflation zones (departure zones for sand and hence liable to scouring). Other woody species, mainly various acacias (especially *Acacia raddiana* and *A. senegal*), *Balanites aegyptiaca, Euphorbia balsamifera* and *Persica salvadora*, are planted in more stable zones.
- ***On coastal dunes.*** Only halophytic woody and grassy species (those resistant to soil salinity and salt spray) are able to grow on coastal dunes. These include *Nitraria retusa, Tamarix aphylla, T. senegalensis, Casuarina equisetifolia, Atriplex halimus, A. nummularia* and *Zygophyllum* spp.

Descriptions of some of the species used in Mauritania are given in Annex 1.

Planting techniques

Planting period. In Mauritania, planting and restocking in high-mortality zones begin with the annual reforestation season, a period usually corresponding to the rainy season, from July or August to the end of October. When there is insufficient rainfall, as is often the case, seedlings receive additional water before and after planting, so that the tap root can reach the layer of residual moisture in the soil more quickly and the plant can become established.

Density of planting. In arid and semi-arid zones, density will depend on the richness of the soil and the depth of residual moisture, but particularly on rainfall. The lower the rainfall, the greater the spacing along and between planting lines, in order to avoid competition between seedlings and exhaustion of the soil's water reserves. However, the density selected must allow the slowing and suppression of wind erosion.

In Mauritania, according to these criteria, planting spacing ranges from 5 × 5 m in squares (400 seedlings to the hectare) or staggered (462 seedlings to the hectare), to 7 × 7 m in squares (200 seedlings to the hectare) or staggered (235 seedlings to the hectare), to 10 × 10 m in squares (100 seedlings to the hectare) or staggered (115 seedlings to the hectare) – although this last density may be increased on highly mobile dunes. The spacing between lines also encourages the natural development of grassy cover. The rule adopted recommends planting one woody seedling per hectare per millimetre of effective rain. Thus, in a region with annual rainfall of 200 mm, the advice is to plant 200 woody seedlings per hectare combined with perennial grassy species.

Preparation of the ground. Planting lines are laid out with a rope 100 to 150 m long, marking the position of the planting holes according to the density selected, either between the counter-dunes perpendicular to the prevailing wind or within the internal grid if the winds come from various directions. Seedlings can also be placed parallel to the fences to form a live fence that may in the short term replace the dry plant matter used for mechanical stabilization. The holes are made along the planting lines shortly before or at the time of planting to avoid having their sides cave in. Where there is little or no surface moisture in the sand, an initial watering is recommended before actual planting in order to moisten the dry layer above the residual moisture.

Planting. When taken from the nursery, the seedlings and/or cuttings in containers are carefully selected and well watered. Only vigorous specimens with a well-developed aerial and root system are sent to the planting site. Care is taken to avoid their exposure to sun or wind during transport. The ideal ratio between the aerial and root parts is 2.5 or 3 to 1.

Given the poor spread of rainfall in dry or semi-dry zones, planting must be carried out during a very short period and should preferably be started after a good rain in order to ensure that the seedlings take well. Planting is always carried out during the coolest hours, but can be carried out during the day if the weather is cloudy or rainy.

The success of planting depends on speed of execution, good organization, good distribution of teams on the ground, and the quantity of rainfall.

At the time of planting, the polyethylene pouches must be removed (slit along the bottom and down the side with a very sharp implement), collected and destroyed.

Planting can be done either on the surface with the neck of the seedling at ground level, or at a depth, so that the neck is level with the moist sand, thus allowing the seedling to use the deep moisture of the dune soil from the start.

In order to protect seedlings from the abrasive effect of the wind and give them a good chance of taking root, the aerial part should be at least 30 or 45 cm above the soil. The root system must not be placed in direct contact with dry sand. After watering, the holes must be filled in with wet sand. At the foot of the seedling, the soil is then covered with dry sand to prevent watering water from evaporating.

There is no further application of water during the dry season.

On live and moving dunes, it is recommended that seedlings be watered with a hollow metal cylinder, 40 cm in diameter and 40 cm in height, which allows the water to trickle directly down to the moist layer of soil. Knowing that an application of 10 litres of water moistens 25 cm of sand, the amount of water to be used depends on the depth of residual moisture.

M. OULD MOHAMED

Watering and planting with a cylinder

M. OULD MOHAMED

Aerial sowing

Direct sowing or sod seeding. This technique of broadcast sowing in seed holes is inexpensive and uses much less labour than planting. However, the sowing period must be carefully chosen, usually after a rainfall of more than 50 mm. The results in terms of germination and growth depend on the quantity and frequency of rainfall during the current season. In arid and semi-arid regions, direct sowing tends to have a low success rate with a generally very high mortality of seedlings after germination.

Only species with large seeds, such as acacias and balanites, can be sown directly, since they contain sufficient nutritional reserves to nourish the seedling until the roots are well established and capable of absorbing moisture and nutrition from the soil.

The seed may receive some treatment prior to sowing, in the form either of soaking in hot or cold water, or immersion in sulphuric acid to speed up germination. It is also best to coat the seed with rodenticide and insecticide.

In Mauritania, broadcast direct sowing can also be carried out with local annual and perennial grassy species or Cucurbitaceae (*Colocynthus vulgaris*), although the success rate will depend solely on rainfall.

For some years, broadcast sowing from aircraft has also been tried out in several of the country's *wilayas* after good rainfall has been recorded. This method is fairly expensive, however, and requires large amounts of seed and a good knowledge of meteorological conditions, particularly wind direction and speed.

However, prudence is required regarding any scaling up of this type of sowing, and careful study of germination and growth rates of the various species in these difficult zones is needed.

Fencing off and posting of guards. Dune fixation installations are extremely delicate elements and require constant all-round protection for several years, especially against wandering livestock. Guards are preferably recruited from villages or towns near the areas requiring protection. Rural communities also have a major role to play in ensuring the sustainability of these woody and grassy plantations, which are the source of future income (fuelwood, stakes, seed, fodder, etc.).

4. An experience in sand dune fixation: rehabilitating and extending the Nouakchott Green Belt

Between 1975 and 1992, the initial establishment of the 750-ha green belt around Nouakchott did not take account of the rapid growth in population, which now numbers almost 1 million, or of the immense pressure on the capital's urban and periurban space during recent decades.

Seeking to rectify this situation, in 1999 the Government of Mauritania sought the assistance of the Government of the Walloon Region of Belgium to launch a realistic programme to rehabilitate and extend the plantations already established around Nouakchott in order to protect its socio-economic infrastructure against sand encroachment.

On the initiative of Prince Laurent of Belgium, this assistance was provided between 2000 and the end of 2007, with the establishment of 800 ha under the Support for the Rehabilitation and Extension of the Nouakchott Green Belt Project, financed by the Walloon Region and executed by FAO in partnership with the Mauritanian Government. The World Food Programme (WFP) undertook to provide food incentives for the workers.

The development objective, as expressed in the project document, was to boost sand encroachment control and the protection of Nouakchott's socio-economic infrastructure by ensuring the permanence, extension and sustainable management of the capital's urban and periurban forest stands with the participation of cooperative groups, associations, NGOs and professional associations, in close coordination with administrative, municipal and technical authorities.

The immediate objectives were:

- to guarantee the permanence and renewal of the tree cover already established;
- to prepare, organize and maintain participation of local inhabitants and authorities in the protection, maintenance and extension of forest plantations;
- to design a medium- and long-term urban and periurban forestry programme for the city of Nouakchott;
- to adapt and carry out small-scale trials on fixation measures for coastal dunes.

During implementation of the project, 800 ha of inland dunes were fixed under government supervision northeast of the capital in order to back up the first reforestation activities undertaken between 1987 and 1992 by the Mauritanian Government and LWF.

A trial was also carried out on 7 ha in order to encourage renewal of the coastal dune belt to the west of the capital.

In rural areas of Trarza *wilaya*, the project intervened on the request of local authorities and communities to check the renewed sand encroachment that was threatening these areas, reduce degradation of their environment and protect their socio-economic infrastructure. With the active participation of the local population and technical support from the project, 50 ha were mechanically stabilized and planted.

Since its inception, the project has benefited from experience acquired by:

- the PLEMVASP project between 1983 and 1997;

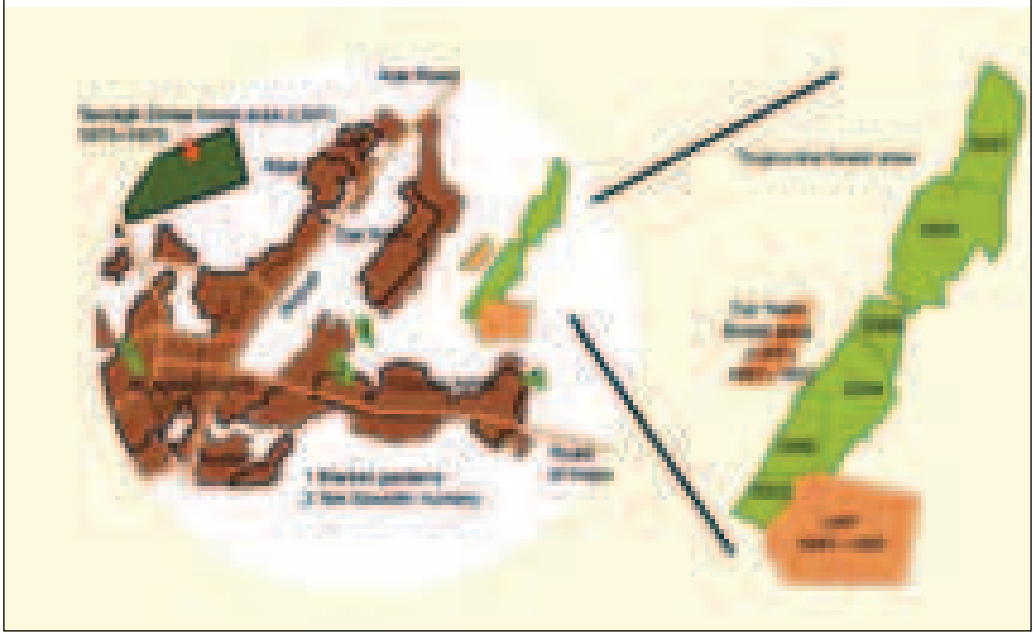
- LWF, which carried out the first dune fixation work around the capital between 1975 and 1992 under the Nouakchott Green Belt Project;
- studies carried out by FAO in 1984 on the dynamics of wind and sand and on the establishment of a sand encroachment map of the area around the capital.

PRELIMINARY STUDIES

Survey of forest and horticultural areas within project intervention zones

At its inception, the project carried out a survey in order to draw up a map of existing forest areas: 1 270 ha at Toujounine, Dar Naïm and Tavragh-Zeina, together with their extension of 857 ha during the 2000 to 2007 seasons at Toujounine (Figure 13), the Nouakchott coastal strip and at Tiguint and Tendghaïdsat in the Trarza *wilaya*.

FIGURE 13
The Toujounine intervention zone



J. SHADID

Dar Naïm horticultural zone

The main horticultural areas, totalling 150 ha on the outskirts of the capital, were also surveyed and mapped.

Thanks to intervention under the project, all the forested areas located in and around the capital were included by decree in urbanization plans for Nouakchott city in order to ensure their protection and guarantee the sustainable protection of socio-economic infrastructure against sand encroachment.

Analysis of meteorological data

The Nouakchott Airport Meteorological Station (18°05' north, 15°56' west) is situated some 5 km west of the Toujounine plantation. Data on temperature, rainfall, relative humidity, evaporation, hours of sunlight and wind speed were recorded between 1946 and 2007 – 62 years – and have now been collected, analysed and computerized (Table 1).

The Tiguint Meteorological Station in Trarza *wilaya* (17°15' north, 16°00' west) started to keep records of rainfall and the number of days of rain in 2002, the year of intervention under the project at Tiguint and Tendghaïdsat in Trarza *wilaya* (Table 2).

TABLE 1
Summary of meteorological data during the period of the project, Nouakchott Airport

Parameter	2000	2001*	2002	2003	2004	2005	2006	2007	Average 2000–2007
Temperature (°C)									
Average minimum	19.1	20.7	20.8	20.8	20.5	21.2	20.4	20.1	**20.4**
Average maximum	30.2	34.2	33.4	33.3	33.3	33.6	34.3	33.4	**33.2**
Overall average	24.6	27.5	27.1	27.1	26.9	27.4	27.3	26.7	**26.8**
Average absolute minimum	15.9	17.3	17.3	17.4	16.8	17.4	16.9	16.9	**17.0**
Average absolute maximum	36.9	41.0	40.4	40.1	40.2	40.4	42.3	39.4	**40.1**
Relative humidity (%)									
Average minimum	32.7	33.7	31.7	35.1	34.2	35.7	35.8	31.0	**33.7**
Average maximum	73.7	81.6	75.6	79.2	79.9	80.4	77.3	73.7	**77.7**
Overall average	53.2	57.6	53.6	57.1	57.0	58.1	56.6	52.3	**55.7**
Average absolute minimum	10.8	10.5	10.2	11.8	11.0	9.5	11.7	10.8	**10.8**
Average absolute maximum	90.6	98.3	96.7	96.1	97.4	98.0	94.1	95.5	**95.8**
Rainfall									
Total (mm)	75.9	127.7	32.5	45.4	25.8	184.2	64.9	15.5	**71.5**
Total number days of rain	9	9	7	7	9	17	13	7	**9.8**
Evaporation (Piche)									
Average (mm)	198.2	198.3	200.5	186.2	190.6	254.0	282.8	311.4	**227.8**
Sunlight									
Length (hours)	223.2	263.6	246.5	241.4	248.6	252.9	265.5	260.9	**250.3**
Wind speed (m/s)									
Average	4.5	4.4	4.7	4.5	4.6	4.1	4.4	4.5	**4.5**
Maximum	16.2	16.8	17.8	16.8	15.9	15.5	17.2	15.2	**16.4**

* No planting or restocking during this year.

TABLE 2
Rainfall at Tiguint

Rainfall	2002	2003	2004	2005	2006	2007	Average 2002–2007
Total mm	101.7	247.2	164.6	204.3	152.0	111.5	**163.6**
Total number days of rain	11	15	12	18	15	10	**13.5**

M. OULD MOHAMED

Tendghaïdsat village nursery, Trarza wilaya

TREE NURSERIES

In general, the positioning of a permanent nursery to supply an area where reforestation work will be carried out over a relatively long period needs to take account of:

- the relief of the terrain: the ideal ground is flat, slightly sloping lengthwise, cleared, levelled and without stones;
- the quality of the soil, which must be of light or medium-textured loamy sand, easy to work, well drained and free of nematodes and dangerous cryptogams;
- a permanent supply of sufficient good-quality water;
- a central situation or proximity to reforestation areas;
- all-season ease of access;
- availability of sufficient labour;
- the capacity to obtain annual supplies of substratum to ensure the desired production.

The nursery area is protected against prevailing winds, runoff from rainfall or secondary buildups of water, livestock, fire, birds and plagues of locusts. It is also surrounded by a wire netting fence, lined on the inside with a preferably thorny life fence or with fences of plant or synthetic material. Permanent posting of guards is also advised.

Some nurseries have been set up and managed by communities. For example, the Tendghaïdsat village nursery in Trarza *wilaya*, covering 400 m² and with an annual production capacity of 25 000 seedlings, was set up using a participatory strategy with the rural community and the support and supervision of technical experts from the project.

An example: Ten Soueilim nursery

The nursery in the Ten Soueilim forest research station, Dar Naïm *moughataa* (prefecture), Nouakchott *wilaya*, meets all the criteria perfectly.

The plot selected for project activities covers an area of 1 500 m² and is intended to produce 60 000 seedlings each year for planting and restocking in the Toujounine reforestation zone, the Nouakchott coastal dune zone and the Tiguint reforestation zone in Trarza *wilaya*.

The area of the nursery was surveyed and mapped on a 1:200 scale at the start of the project, and the map was then updated each year. The map indicates the position

of seed beds depending on annual production and species for the storage of recipients (polyethylene pouches), raised beds for the production of bare roots, paths and supply points for irrigation water.

In this nursery, the seed beds are 1 m wide, 10 m long and 10 cm deep, and are separated by a 50-cm-wide path. They must always lie in an east-west direction in order to provide the young seedlings with the same length of daylight and thus ensure a uniform production. The beds are arranged on either side of the central path and each contains 1 000 seedlings.

The main modes of production are through sod seeding in black polyethylene pouches (with flat dimensions of 25 cm × 12.5 cm, giving a volume of 1 256 cm^3), cuttings in pouches and, as an experiment, bare roots in raised beds 10 m long, 1.1 m wide and 30 cm high.

M. OULD MOHAMED

Ten Soueilim nursery

M. OULD MOHAMED

Placing pouches in nursery beds

With a view to accustoming the seedlings to the sites where they will be planted, the substratum used is made up of dune sand and a small amount (10 to 15 percent) of organic fertilizer.

Before the pouches or raised beds are filled, the substratum is carefully mixed and sieved to produce a uniform texture and get rid of undesirable elements (wood, stones, etc.).

Sowing is one of the main nursery operations. It is important to:

- know the provenance and harvesting date of the seed;
- have healthy seed with a high germination rate (a germination test must be carried out for each species before sowing);
- water the recipients copiously prior to sowing in order to allow the germination of weeds and their removal, while avoiding any hardening of the substratum;
- soak the seeds in hot or cold water depending on the thickness of the cuticle prior to placing 2 to 3 of them in each recipient; the depth of sowing will depend on the size of the seed, but should be about 1.5 to 2 times its diameter; for the production of bare roots, the planting holes in the raised beds are arranged every 10 cm in lines 15 cm apart, making a density of 70 seedlings per square metre;
- sow slow-germinating species first;
- water by spraying after sowing and until emergence, making sure that the seeds are not ejected out of the seed beds;
- protect seeds against birds, insects and rodents with the aid of netting, insecticide and rodenticide;
- monitor the germination time of each species and if necessary resow in order to obtain seedlings of a uniform height.

Certain species, such as *Tamarix aphylla* and *T. senegalensis* used to fix coastal dunes, are multiplied in the nursery through cuttings. Taken from selected trees, the cuttings are 15 to 20 cm in height, with a diameter of 2 cm, and are pushed into the pouch at a slant, leaving one or two buds above the ground. The substratum is then pressed down around the cutting.

The following care is given to the young seedlings:

- Maintenance watering: This is carried out with a sprinkling can twice a day in the cooler hours, supplying 20 litres per square metre per watering; as the seedlings

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Bare-root production of Prosopis juliflora *in raised seed beds*

grow, they are watered less often in order to accustom them to their future environment.

- Thinning: If germination is very good, only the most vigorous seedling in each recipient is retained.
- Pruning and stripping of roots: When the seedling's root system starts to come out of the pouch, about four or five weeks after germination, the recipients are moved sideways to prevent the tap root and certain lateral roots from penetrating too deeply into the ground. This action encourages the development of radicles in the substratum and also results in good lignification of the aerial part of the seedling. The operation is carried out when the weather is not too sunny and takes place every two to three weeks until the seedlings are planted out; after the roots have been pruned, the treated seed beds are well watered. For the production of bare-rooted seedlings, regular pruning of the tap root and secondary roots is carried out to a depth of 25 to 30 cm with well-sharpened spades (with blades 30 to 35 cm long and 20 cm wide).

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Watering of seedlings in the nursery

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Pruning of bare roots

- Regular weeding of the seed beds.
- Shading of the beds: In order to protect the young seedlings from the sun, they have to be shaded in some climates; this protection is gradually removed as they grow.

The calendar of work is as follows for each growing season:

- March to April: repair of the general infrastructure of the nursery, addition of substratum, filling of pouches, preparation of nursery beds for the pouches and raised beds for the bare roots, installation of windbreaks, purchase of seed;
- April: pouch sowing of slow-growing local woody species (*Acacia raddiana, A. senegal, Leptadenia pyrotechnica, Nitraria retusa*) and grassy species (*Aristida pungens, Panicum turgidum*) and propagation by cuttings in pouches (*Tamarix aphylla, T. senegalensis*);
- May: pouch sowing and bare-root sowing in raised beds for *Prosopis juliflora*;
- July to October: watering, regular sideways shifting of pouches and monthly pruning of bare-root seedlings, pest and disease control, various types of maintenance and posting of guards until planting out.

If this calendar is followed, the best quality seedlings can be obtained for successful planting out.

The project gave priority to the production of indigenous woody and grassy species rather than non-indigenous species.

Throughout the project, stress was laid on ongoing practical training of staff, the production of healthy lignified seedlings with an orthotropous root system (neither spirally wrapped nor crooked) and a good quantity of secondary roots.

The transport of substratum, the filling of pouches and raised beds, and the installation of the pouches in their beds require 20 to 25 person-days for one month. Starting at sowing time, the daily staff at the nursery is made up of one team leader, two male workers and ten female workers, for an average annual production of 60 000 seedlings.

The average cost price per seedling is US$0.25.

MECHANICAL DUNE STABILIZATION

In the project intervention zones, the checkerboard wattling technique may be selected, taking account of the directions of the prevailing winds. On average, and depending on dune type and shape, 600 to 1 200 linear metres of fencing (around the edge, counter-dunes

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Nursery beds containing Panicum turgidum

perpendicular to the direction of prevailing winds, and interior wattling) were installed per hectare.

As stabilization material, the project decided on unwoven branches of *Leptadenia pyrotechnica* and *Prosopis juliflora*, which were placed directly in a previously dug trench, a method that proved much less arduous and time-consuming than that of the woven fences previously used. Sustainable extraction of plant matter in the form of pruning to improve mature stands near the areas to be stabilized had no negative effects on the growth of these stands.

When installing the plant matter, care is taken to ensure the permeability of the fences (30 to 40 percent left empty) and observe a height of 1 to 1.25 m. Cutting,

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Cutting with a saw

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Cutting with a chainsaw

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Transporting plant matter

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Installing plant matter

transporting and installing the plant matter takes two to three team-days' work by a 20-person team (1 leader and 19 workers).

Depending on the distance from the supply source, one person installs an average of 6 to 8 m of fencing per day. The cost price per linear metre installed is thus US$0.65.

BIOLOGICAL DUNE FIXATION

Once the dunes have been stabilized, they can then be fixed definitively by installing perennial grassy and woody vegetation.

For each planting season, planting and restocking start as soon as the first rains fall.

The ideal is to plant as soon as the new and residual soil moisture meet, which takes place a few days after good rain. A well-moistened soil means that the time taken in planting is reduced to a minimum and the seedlings take root well, thus reducing the planting costs per hectare. In the case of insufficient rainfall, supplementary water is given to each seedling in order to make up for the depth of residual moisture.

The positioning of species on the ground is a very important factor for successful planting.

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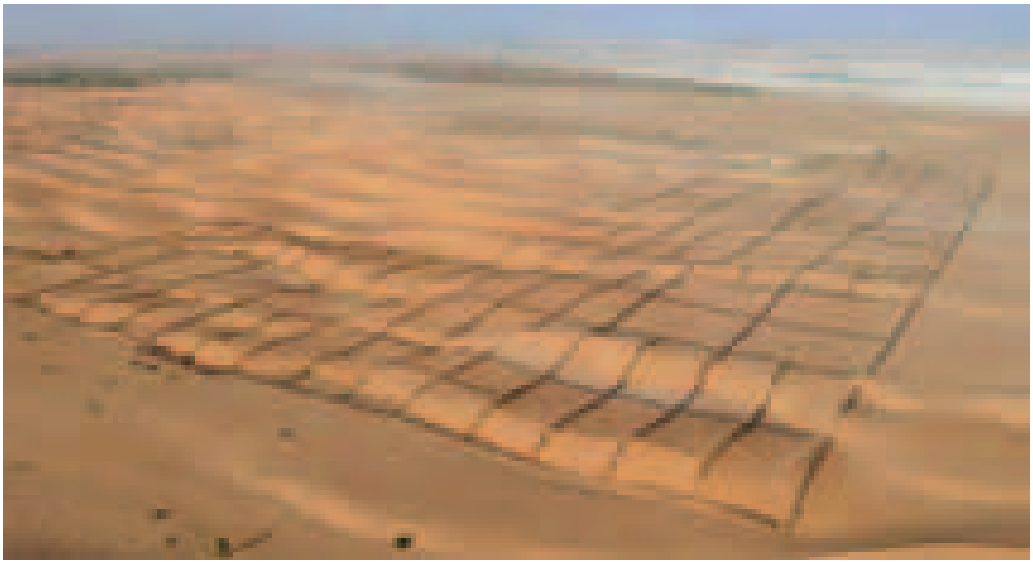
Installing a palisade or fence



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General view of a mechanically stabilized area

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Transporting water for watering

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Watering Acacia senegal *seedling after planting*

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Raising and planting the Nouakchott coastal strip

On inland dunes, three areas are considered: the accumulation zone, the deflation zone and the intermediate zone. The choice of species to be planted in each zone depends on their particular suitability. In the case of the project, *Prosopis juliflora* (the only woody species that has so far had any solid sustainable success on this type of soil) and *Aristida pungens* are planted on very mobile strip dunes in accumulation zones. Deflation zones are planted with *Leptadenia pyrotechnica, Aristida pungens* and *Panicum turgidum*, while other slow-growing woody species such as *Acacia raddiana* and *A. senegal* are planted in more stable intermediate zones. Broadcast direct sowing (of local grassy species) and pouch sowing (*Colocynthus vulgaris* of the Cucurbitaceae family) may be tried, but the success rate depends on rainfall.

On coastal dunes, planting concentrates on halophytic species, resistant to a high level of salinity, such as *Nitraria retusa, Tamarix aphylla* and *T. senegalensis*.

In the case of woody and grassy species produced in pouches, only well-lignified vigorous seedlings are selected. These are watered copiously immediately before being transported to the planting site, while rejected seedlings are disposed of. The selected seedlings are transported in a van with a tarpaulin cover to avoid exposure to wind and sun.

In the case of species produced with bare roots, the seedlings are sorted, and the roots are dressed and wrapped in well-moistened jute bags to protect them until they are planted.

Both woody and grassy species are planted at 5 × 5 m intervals in squares (making a density of 400 seedlings per hectare). With a view to encouraging development of the grassy cover and avoiding competition between trees in this ecosystem, which receives little rainfall, the distance between seedlings may be increased to 7 × 7 m in staggered rows (making a density of 235 seedlings per hectare) or even 10 × 10 m, also

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General view of the Toujounine plantation

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Natural regeneration of grassy cover

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Natural regeneration of Cyperus rotundus

in staggered rows (making a density of 115 seedlings per hectare) – although the latter density is increased on particularly mobile dunes.

The pouches are removed at the moment of planting in order to avoid spiral wrapping of the root system and gradual strangulation of the tap root. The pouches are collected up and destroyed to avoid polluting the environment with plastic rubbish.

Successful planting obviously depends on rainfall, the absence of parching sand-bearing winds and the organization and speed of field teams. During this period, the teams are closely supervised by technical experts from the project in order to ensure a maximum success rate for the seedlings.

On average, the mortality rate is lower than 30 percent for woody species planted in clods (after removal of the pouches), while the success rate is almost 80 percent for grassy species. However, bare-root planting of woody species will give good results only in zones with annual rainfall of more than 150 mm.

Restocking is carried out each year in sectors with a high mortality rate.

Thanks to intervention under the project, there has been major natural regeneration of the grassy cover, particularly with *Aristida pungens, Panicum turgidum, Cyperus rotundus, Elionorus elegans* and *Eragrostis* spp., in and around all the areas treated.

At planting time, three team-days' work by a 20-person team, evenly distributed on the ground, allows staking out (marking of lines where the seedlings are to be planted), the digging of holes, actual planting and the watering of seedlings.

One person plants an average of 15 seedlings per day, with a cost of US$0.3 per plant.

PROTECTION OF REFORESTED AREAS

The most appropriate solution is to post permanent guards for the intervention zones to prevent livestock (camels, sheep, goats and donkeys) from wandering from dedicated livestock corridors, while illicit human activities (collection of wood, cutting of fodder) are reduced to a minimum.

The guards are preferably recruited in villages near the planted areas. No wire netting fence is placed around the areas, for this method is too time-consuming and costly, and also lacks reliability in the short term.

The inhabitants are involved and made aware of the need to respect and preserve this forest asset, which will very quickly ensure the protection of their infrastructure

(dwellings, mosques, crops, market gardens, roads, etc.) against sand encroachment and more generally prevent degradation of their environment.

On average, one guard is responsible for 50 to 60 ha, although the number of guards is increased close to high-density grazing zones.

The annual cost of protecting planted areas in this way is US$15 per hectare.

MAIN CONSTRAINTS

Potential constraints on the success of reforestation in arid and semi-arid zones include:

- climatic factors: rainfall deficit, parching winds and major differences between daytime and night-time temperatures;
- the lack of involvement of the beneficiary rural population;
- the lack of technical support and training for national institutions and local communities for the effective implementation of forestry programmes;
- the choice and availability of material for mechanical dune stabilization;
- the selection of plant species, both woody and grassy, that are appropriate to the ecosystems in which the work is carried out;
- uncontrollable plagues of locusts.

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Plague of locusts on natural vegetation

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Prosopis juliflora *stand after desert locusts have passed*

5. Participatory approach

In fighting desertification and sand encroachment, the use of a participatory approach has been demonstrated to be key for achieving and securing long-term and sustainable results and positive impacts. The participatory approach methodology entails the following stages:

- the choice of sites to be treated, taking into consideration the seriousness of sand encroachment, the willingness of the local inhabitants to carry out work following appropriate techniques, the local authorities' approval of these sites and the priorities set;
- the establishment of village committees in the target zones in order to ensure the social organization of the work and supervise management and monitoring of the established timetable;
- the signature of agreements regarding the nature of the operations to be carried out, the prescribed time frames, the necessary participation, the roles of the committee established by the beneficiaries and the technical training to be provided;
- the training of local inhabitants by field staff (national experts and technicians, project leaders and NGO officers) in the production of seedlings, installation of wattling, planting, monitoring and posting of guards;
- implementation of the various activities and operations on a contractual basis with the rural population in order to ensure the local people's effective ongoing participation and assumption of responsibility for the planned work.

Implementing the participatory approach as described above has provided the following benefits:

- a shift in the local population's attitude from fatalistic to positive;
- consideration for the understanding and views of the village communities in regard to sustainable land management;
- commitment of the local inhabitants and their participation as stakeholders in combating sand encroachment;
- greater awareness and strengthened capacity of local communities;
- adoption of simple and reliable techniques;
- relief from difficult economic conditions, provided by incentives in foodstuffs supplied to the local inhabitants;
- reduction in encroachment and environmental pressure from harvesting, thanks to appropriate, reliable techniques that are easy for the rural population to adapt and reproduce.

The activities carried out contributed to the immediate well-being of rural inhabitants by protecting their socio-economic infrastructure, improving their standard of living and slowing the exodus toward urban centres.

IN URBAN AND PERIURBAN AREAS

In the case of the Nouakchott green belt, the particular features of the urban and periurban environment required an appropriate approach. Various factors were taken into account:

- the inhabitants of these zones are often relatively impoverished people who support themselves with small jobs and casual labour;
- some inhabitants, often tenants (officials and traders), may not be directly concerned or may show no interest in sustainable activities to preserve the environment;

- the installations are State-owned and offer few opportunities for the use of forest products or by-products.

The approach envisaged may thus be participatory, but not basically community-focused, inasmuch as the latter is less appropriate in the urban context. The project therefore designed an approach based on execution of activities under State supervision with workers receiving monthly salaries, rather than counting on the disinterested collective participation of communities living in these zones – who have neither the motivation nor the time, since most of their time is taken up with various other activities in order to meet their subsistence needs.

With a view to ensuring the sustainability of existing and future schemes, the project selected a participatory approach that linked the administrative and municipal authorities concerned, the technical services and the communities directly affected by sand encroachment in the target zones. In this context, it adopted the methodology tested on a small scale during the first planting season on green belt intervention sites:

- establishment of contacts in order to identify socio-professional organizations (cooperatives, cooperative unions, national NGOs, etc.) directly concerned in the conservation and management of forest stands;
- organization of regular meetings with the administrative and municipal authorities of these *moughataas* (prefectures) and also with the leaders of the cooperatives and NGOs selected; these meetings mainly focused on:
  - the transmission of information and explanation of the various project objectives, particularly regarding optimization and consolidation of benefits with the support of periurban organizations, with a view to ensuring the sustainable management and permanence of forest interventions;
  - the search for guarantees from administrative and municipal authorities regarding the protection of schemes and the execution of harvesting felling, with the various partners respecting the clauses in the letters of agreement;
  - the readiness of the socioprofessional organizations involved to undertake the activities defined, their organization and the resources to be put in place;
  - the commitment of technical services to ensuring specific training for field staff, and ongoing monitoring and evaluation of the work carried out;
- organization of visits to the various plantation areas with the leaders of the identified cooperatives and NGOs so that they can evaluate the real nature and

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Meeting of the management committee concerned with combating desertification

volume of the activities to be undertaken (nursery, wattling, planting, harvesting, posting of guards, use and sale of forest products and by-products, etc.);
- establishment of firm commitments among the parties concerned through the drafting and signing of letters of agreement with the definitive approval of the administrative authorities;
- monitoring and evaluation by the project and the relevant technical services of sound execution and observance of the calendar of work fixed at the start of each planting season.

IN RURAL AREAS

In rural areas, at the request of local communities supported by local authorities, letters of agreement were drawn up and signed among all partners in order to define their effective roles and responsibilities for carrying out the work and continuing the activities after the project on a sustainable basis. These agreements laid out the nature of the operations to be undertaken by the parties concerned and the participation needed in order to achieve the designated objectives within the time frames laid down, as well as in the longer term.

6. Management and harvesting of plantations

Management and harvesting activities have the main aim of ensuring the sustainability of plantations in order to maximize the beneficial effects of dune fixation work and prevent the sand from starting to move again.

In arid and semi-arid zones, the contribution of reforested dunes to wood and fodder production is secondary in the first years of the plantations' establishment, when the environment created is still fragile and unstable. Moreover, the main purpose of the plantations is long-term protection of socio-economic infrastructure (roads, irrigation channels, dwellings, water towers, etc.) and of the farm and grazing land needed for sustainable economic and social development.

The main measures to be taken are:

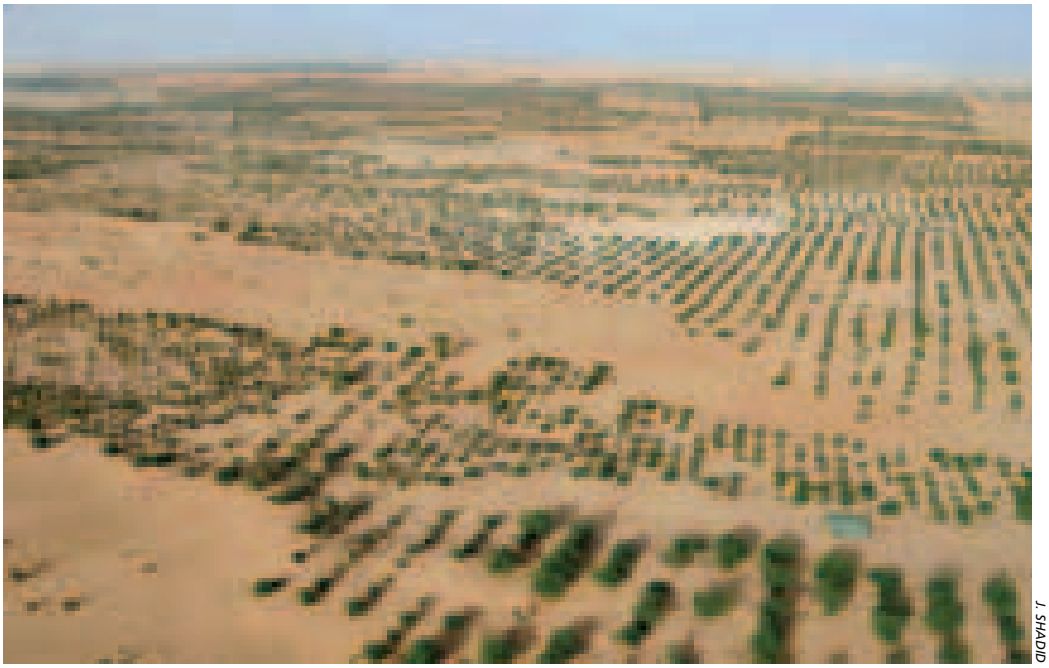
- the establishment of a grazing ban for these areas with very strict guarding, complemented if necessary by the installation of wire netting fences (which are unfortunately fairly expensive and hard to maintain) or live or dead vegetation fences around plantations; clearly defined corridors make it easy to cross plantations without damaging them;
- the education and supervision of local inhabitants and the search for their real participatory involvement in preserving their environment.

With a view to ensuring the sustainability of all the planting carried out, it is thus important to build on the results achieved by previous projects and programmes. Forest harvesting studies have provided interesting data on the felling methodology, technique, height and period, the appropriate equipment and its availability on the local market, the organization of work, and regeneration through resprouting.

The reforestation work carried out around Nouakchott had the main objective of stabilizing dunes threatening the capital's socio-economic infrastructure. Management of these stands is intended to regulate harvesting by maintaining the beneficial effects of curative action, especially that concerned with dune fixation, while sustainably protecting the forest capital established. In this case, the harvesting of mature stands principally of *Prosopis juliflora* is considered a silvicultural operation intended to rejuvenate the vegetation. Felling for health, maintenance and clearing purposes allows collection mainly of the plant matter needed for mechanical dune stabilization. In the future it will be able to meet part of the population's needs for fuelwood, charcoal, poles and fodder.

These management activities focus mainly on:

- establishment of permanent random observation plots to identify the growth and production of *Prosopis* spp. of harvestable age, and to study the vigour of this species in resprouting; on these plots, harvesting consists of cutting all the poles on each tree at a height of 1.5 m in order, if necessary, to place future fresh shoots out of reach of the teeth of livestock; since most of the trees resprout very well, this technique was adopted for management of the plantations;
- ongoing training of field workers;
- organizational and operational aspects of work in the field;
- the harvesting calendar (March to July/August) for plots in the selected stands;
- purchase of appropriate equipment and tools available on the local market: bucksaws and various blades, shears, machetes, hatchets, gloves and chainsaws (for large-diameter branches);



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Treatment of mature Prosopis juliflora *stands*

- ongoing awareness-raising, through work meetings and field visits involving national technical services, regional authorities, local communities, cooperative groups, NGOs and others; such activities lead to greater awareness and participatory organization, with a view to gradual assumption of responsibility for the various interventions, thus ensuring both the success of such interventions and also the permanence and expansion of existing forest plantations.

7. Institutional aspects

GOVERNMENT SUPPORT

When executing environmental protection and rehabilitation programmes, it is important to have a clear picture of the national coordination body set up by the government and responsible for implementing national policies.

Mechanisms for consultation and coordination with the lead agency must be established to ensure that project activities are in line with the national strategy concerning desertification control and sustainable natural resource management.

Basic and refresher training of staff

Foresters responsible for execution of the approved programmes receive ongoing practical training on the various aspects of sand encroachment control and silvopastoral development, especially:

- understanding of the wind phenomenon, the origin and dynamics of sand and its encroachment;
- the approach, strategy and methodology of action to combat sand encroachment;
- techniques for the installation and maintenance of mechanical dune stabilization works, seedling production, planting and plantation management.

These experts in turn train field workers and the guards responsible for surveillance of plantations. They also take part in the work meetings and field visits organized by the technical services of the government authorities concerned, with a view to raising the awareness of community leaders, NGOs, etc. In addition, they help in the teaching and on-site application of techniques for sand encroachment control and sustainable environmental protection.

Briefings on the various technical approaches during national and international workshops and seminars play an important role in boosting the capacities of technical staff.

Contacts and support activities

A policy of close collaboration with national and international institutions (UNDP, FAO, WFP, cooperative agencies, etc.), civil society and the target population is vital for the success of any desertification control programme.

Dissemination and extension of advances

Publication and dissemination of experience and advances in the development of techniques, interventions and approaches are important, both nationally and internationally.

In this connection, reports, PowerPoint or other presentations, leaflets and posters presenting the experience and results obtained in nurseries, mechanical and biological dune fixation, plantation management and protection and participatory planning play a major role in mobilizing and supporting all those involved.

ADMINISTRATIVE SUPERVISION AND PROJECT MANAGEMENT

Administrative supervision

Once the plan of operations for the project has been approved and signed by the various partners (donor, officer responsible for execution and government body with counterpart responsibility), a work programme and budget concerning objectives, activities and results to be achieved are drawn up at the start of each financial year. The annual plan covers:

- the programme of work for the nursery (number of seedlings to be produced for each species) and the calendar of activities to be undertaken (repair of infrastructure, installation of windbreaks, purchase of seed, supply of substratum, preparation of seed beds, filling and installation of recipients, sowing, watering, stripping of root systems, plant health treatment, various types of care, and guarding);
- surveying and mapping of the area(s) selected in the project intervention zones;
- mechanical stabilization work to be carried out (harvesting of mature stands, transport and installation of the plant matter collected for the construction of fences, and, if necessary, internal wattling);
- inception and duration of planting and restocking (watering and transport of seedlings selected in the nursery, on-site distribution, staking out of lines where seedlings are to be planted depending on the planned density, planting itself and, if rainfall is poor, supply of water to each seedling);
- needs in terms of staff and the corresponding budget for the nursery, work in the field and guarding;
- other activities to be pursued during the current season (meteorological studies, participation of technical staff in national and international seminars and workshops, training of the labour force, meetings with local communities, etc.).

The plan also covers:

- the timetable of work (Annex 2, Table 1) in terms of objectives, outputs and activities: for each activity, the responsibilities of the various engineers, technical experts and others will also be listed; management activities (six-monthly and annual reports, budgets, technical support and evaluation missions, etc.) are also given in this table;
- the contribution of the donor government (Annex 2, Table 2): detailed budgetary division regarding technical and field staff, administrative staff, national and international consultants, training within the country or abroad, permanent equipment and expendable items to be acquired, operation of fleet of vehicles and office expenses, etc.;
- the contribution of the national government;
- the contribution of the official partner(s).

Project management

In order to achieve the immediate objectives of the project, it is vital to ensure a sound management of technical and ground staff and the corresponding budget so that the activities laid down in the plan of operations can be carried out.

At the start of and during each financial year, various factors must be known and monitored.

- Requirements in terms of staff for each activity and an estimate of their cost (Annex 2, Table 3): The total number of person-days for each activity (nursery, field work, guarding, administration) and the relative budget estimates must be included in the annual plan of work, together with the contribution of the donor government (Annex 2, Table 2). In the case of projects executed under government supervision, according to the national labour code, a fixed-term work contract must be drawn up, laying down the responsibilities and duties of both employer and workers, and this contract must be signed by the interested parties, with the involvement of the National Labour Office.
- The annual production of seedlings in nurseries (Annex 2, Table 4): Production is recorded according to species, production method and size of the area to be planted.
- The number of person-days and weekly progress on activities regarding mechanical stabilization in the project intervention zones (Annex 2, Table 5): At the end of the season, this table shows the number of linear metres per person-day for the

installation of fences (boundary, counter-dunes and internal wattling), information important in establishing the cost of the activity per hectare and planning the allocation of staff for future planting seasons.

- The balance sheet for planting and restocking on each planting area (Annex 2, Table 6): This shows the number of seedlings planted or replaced for each species and the cost per hectare in person-days, and allows an estimate to be made of the length of future planting seasons, depending on rainfall.
- Records of the monthly wages of field staff in nurseries, dune fixation and guarding (Annex 2, Table 7): These important records tabulate, for each worker, the number of days worked, the gross and net wages in local currency and United States dollars, the amounts allocated for employer's social security contributions and leave paid by the project, and the national social security contributions paid by the staff themselves. These records are signed by the project director and the worker at the time of payment, thus avoiding any argument between the parties involved until the end of the stipulated contracts.
- The number of person-days and the monthly cost of nursery and fieldwork (Annex 2, Table 8): This table allows analysis during the year of the number of person-days used and the expenditure involved, for comparison with the annual budget forecast given in Annex 2, Table 3. It is clear that the final balance must be positive or nil, even if one activity shows a negative balance.
- The monthly and annual balance sheet of project expenditure, broken down into the various budget items (Annex 2, Table 9): The budget forecasts mentioned in this table are compared with actual expenditure, thus allowing a clear picture of the monthly and annual balance for each expenditure item. The balance may be negative within an individual item, but the overall balance must be positive.
- The annual acquisition of equipment, non-expendable and expendable items (Annex 2, Table 10): At the start of each financial year, an inventory must be taken of stored material, so that a list can be made, on the basis of the budget allocated for this purpose, of the new equipment and supplies to be purchased for the anticipated work.

The various tables are regularly updated so that progress on all the activities planned annually by the project (seedling production, mechanical stabilization, biological fixation, forest harvesting, protection of treated areas, etc.) and the sums allocated for these can be monitored against budget forecasts. The tables also show the importance of the daily, weekly, monthly and annual collection and compilation of data, starting with team leaders, then technical staff, for eventual computerization by those responsible for programme coordination.

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Annex 1

Some woody and grassy species used in sand dune fixation

SPECIES USED ON INLAND DUNES

Acacia raddiana Savi

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Natural stand of *Acacia raddiana*

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Acacia raddiana seedling

Main sources. von Maydell, 1983; Jaouen, 1988; Centre Technique Forestier Tropical, 1989.

Other scientific names. *Acacia tortilis* Hayne, *Acacia fasciculata* Guill. & Perrott., *Acacia tortilis* (Forsskal) Hayne *ssp. raddiana* (Savi) Brenan, *Acacia tortilis* Hayne var. pubescent A. Chev.

Common names. Hassaniya: talha; Pulaar: djilouki; Wolof: seing; French: faux gommier, verek; English: umbrella acacia.

Family. Leguminosae, Mimosaceae.

Characteristics. The most widespread tree in Mauritania, it reaches a height of 10 to 15 m, with a hemispheric or spreading crown and hanging branches. Its axillary 2- to 10-cm-long thorns are grouped in pairs. The leaves are alternating and bipinnate, with two to five pairs of pinnules, having six to fifteen pairs of folioles. The highly scented flowers take the form of whitish to pale yellow balls, with characteristically spiral seedpods 10 cm long and 0.5 cm broad.

Distribution. A tree found in the arid and semi-arid regions to the south and north of the Sahara, it grows on sandy or at least deep soils. It is exceptionally drought-resistant, growing with annual rainfall of between 50 and 1 000 mm despite long periods of drought and very high daytime temperatures and night-time temperatures close to 0 °C.

Multiplication. A pioneer species that regenerates well through shoots from the stool or through seeds. There are about 14 000 seeds in 1 kg. In order to obtain good germination in nurseries, seeds are first soaked either for a few moments in sulphuric acid or for several hours in hot or cold water. However, their growth on-site is fairly slow during the first years.

Uses. The species provides excellent fuelwood and wood for charcoal with a high calorific value. It fixes and enriches the soil in nitrogen. It is a particularly useful species for reforestation and dune fixation in zones that have been fairly well mechanically stabilized and protected. It is used to make fences and also supplies poles for construction. It is a good fodder species, and its leaves and seedpods are highly sought after by both domestic and wild animals. It is also used in traditional medicine (as a vermifuge and to treat skin ailments, using the leaves and bark, which contain tannin).

SPECIES USED ON INLAND DUNES

Acacia senegal (L.) Willd.

Natural stand of *Acacia senegal*

Acacia senegal branch

Main sources. von Maydell, 1983; Jaouen, 1988; Centre Technique Forestier Tropical, 1989.

Other scientific names. *Acacia verek* Guill. & Perrott., *Acacia rupestris* Stokes, *Acacia trispinosa* Stokes, *Mimosa senegal* L.

Common names. Hassaniya: ewrwar, eirwar; Pulaar: patouki; Wolof: verek; French: gommier; Sudanese: hashab; English: gum Arabic acacia.

Family. Leguminosae, Mimosaceae.

Characteristics. Gum Arabic acacias are bushes or small trees, reaching heights of 4 to 6 m, with a bole about 30 cm in diameter. The branches are generally highly ramified starting from the base. The small blackish thorns are grouped in threes at the base of the leaves. The fruit is a dehiscent seedpod 10 cm long containing three to eight flat, light-brown seeds. There are about 12 000 seeds in 1 kg. The highly scented flowers are arranged in 3- to 8-cm-long spikes. The root system generally involves a tap-root that is moderately developed for a dry-zone species, with very long lateral roots that colonize the upper layers of soil, stretching up to 15 m from the trunk. The species rarely lives for more than 25 or 30 years.

Distribution. A species typical of the African Sahel from the Atlantic Ocean to the Red Sea, it grows between the 100 and 750 mm rainfall isohyets with average annual temperatures of 30 °C, but cannot withstand frosts. It is well adapted to long periods – eight to eleven months – of drought and prefers well drained sandy soils.

Multiplication. Similarly to *Acacia raddiana*, the seeds have to be treated prior to sowing, whether in nurseries or directly on-site.

Uses. The species supplies the best gum Arabic, which is particularly prized for use in certain culinary dishes, human and veterinary medicine, and the pharmaceutical, cosmetics and chemical sectors (good-quality glue for stamps and envelopes). Its timber is well suited for use both as lumber and as fuelwood, since it has a high calorific value. Thanks to its highly ramified lateral roots, *Acacia senegal* is effective in fixing the soil and is often used in agroforestry. It is much appreciated by livestock, particularly the young seedpods – which is a disadvantage for natural regeneration of the species.

SPECIES USED ON INLAND DUNES

Balanites aegyptiaca (L.) Delile

M. OULD MOHAMED

Balanites aegyptiaca seedling

Main sources. von Maydell, 1983; Jaouen, 1988.

Other scientific names. *Ximenia aegyptiaca* L., *Agialida senegalensis* van Tiegh., *Agialida barteri* van Tiegh., *Agialida tombuctensis* van Tiegh., *Balanites ziziphoides* Mildbr. & Schlechter.

Common names. Hassaniya: teichott; Pulaar: murtoki; Wolof: soump; French: dattier du désert; English: desert date, Egyptian balsam.

Family. Balanitaceae.

Characteristics. A small tree, seldom exceeding 10 m in height and with a diameter of 30 cm, it has a rounded or oval crown. It has a large tap-root and large, strong thorns that are often 8 cm long. Its leaves are bifoliolate with ovoid folioles that are entire and have strong veins. The flowers are a greenish yellow, but fairly inconspicuous. Its fruit grows in date-like drupes and is edible, although slightly laxative. Its seeds vary considerably in size and weight, with from 500 to 1 500 in 1 kg. It is slow growing and takes a number of years before reaching harvestable size.

Distribution. The species is found throughout the Sahelian region and is frequent in the Sudan and the Sahara, except in extremely arid zones. It is a very hardy, adaptable, drought-resistant species, growing equally well on slightly modified dunes and in alluvial valley bottoms, although it does not tolerate areas that are flooded for long periods.

Multiplication. Seeds gathered from livestock excreta germinate very well. Otherwise, they have to be soaked for ten minutes in hot water or for a day in cold water. Seeds are generally sown in nurseries or directly on-site during the rainy season. *Balanites* can also be multiplied through suckers.

Uses. The species has many uses and is held in high regard by the local inhabitants. Its pale to brownish yellow wood is heavy and insect-resistant, and is prized for making tools and small farm implements, and also as construction timber. It provides excellent fuelwood and charcoal. It can be planted as hedges and live fences. Cattle, sheep and camels eat its leaves and fruit, while people eat its fruit and kernels. In traditional medicine, the bark, roots, fruit and leaves are often used to treat diarrhoea, stomach ache, sterility, mental disorders, yellow fever and toothache. Oil for culinary and medicinal use is extracted by pressing the kernels.

SPECIES USED ON INLAND DUNES

Leptadenia pyrotechnica (Forsskal) Decne.

M. OULD MOHAMED

Leptadenia pyrotechnica seedling

Main sources. von Maydell, 1983; Jaouen, 1988.

Other scientific name. *Leptadenia spartium* Wight.

Common names. Hassaniya: titarek, assabay; Wolof: thiekhet, cexet; French: genêt d'Afrique; English: broom bush, desert broom.

Family. Asclepiadaceae.

Characteristics. A bush growing to a height of 1 to 4 m, almost leafless, with green branches reminiscent of European brooms (to which it is not related). Its colourless latex is sparse. Its branches are erect, cylindrical, smooth and pale green. Its flowers are small – 4 mm long – and greenish yellow, grouped in cymes. Its fruit are very narrow, smooth follicles between 6 and 12 mm long and 6 to 8 mm broad. The seeds are flat and oval shaped, with a coma.

Distribution. North Senegal, Mauritania, Niger, Chad, Mali, and the Sahara as far as the Arabian peninsula. It is a plant that grows more on fixed dunes than on live dunes. In the Sahel, its abundance is an indication of environmental degradation following overgrazing.

Multiplication. From seeds sown in nurseries or in the natural environment.

Uses. Grazed by camels but rarely by sheep and goats, and avoided by cattle. Its pith is used as tinder, hence its Latin name. Fishing lines are made from the fibres in its bark. In medicine, the sap of the plant is used as a friction against smallpox and its soaked seeds are used to make an eyewash. The young leaves are used in a sauce for couscous known as *mbumu cexet* in Wolof, and as a substitute for *Moringa oleifera* or *Crataeva religiosa* in other couscous dishes. *Leptadenia* is often planted to fix dunes in the Sahel.

SPECIES USED ON INLAND DUNES

Prosopis juliflora (Sw.) DC.

M. OULD MOHAMED

Prosopis juliflora stand

Main sources. von Maydell, 1983; Jaouen, 1988; Centre Technique Forestier Tropical, 1989.

Other scientific name. *Mimosa juliflora* Swartz.

Common names. Hassaniya: groun lemhada; Pulaar: prosopis; Wolof: prosopis, dakhar, daqar u tubab; French: prosopis; English: honey mesquite.

Family. Leguminosae, Mimosaceae.

Characteristics. A tree reaching a height of 12 to 15 m, with a short bole that can reach 1 m in diameter. It has large numbers of thorns about 1 to 5 cm long. Its leaves are alternate and biparipinnate, with a rachis bearing two or three pairs of pinnules each with 8 to 15 pairs of folioles and no terminal foliole. The young branches are green. The golden yellow flowers grow in small, scented cylindrical spikes. The seedpods are 10 to 20 cm long, containing about 15 seeds, and there are roughly 15 000 seeds in 1 kg. Its root system is very deep, sometimes reaching a depth of 50 m, while its lateral roots grow very close to the surface and often reach a distance of 20 m from the trunk, trapping the morning moisture. In average environmental conditions, it grows between 50 and 60 cm in height per year for the first ten years, then progressively less, until it stops growing in about its fifteenth year. It often lives for more than one hundred years.

Distribution. It is a native of the coastal regions of Latin North America, Central America, Mexico and the West Indies. It is cultivated throughout the tropics and adapts very well to dry zones thanks to its tap-root system. It tolerates high temperatures, low rainfall, and poor, saline soil. It prefers sandy soil, but grows poorly on laterite ironstone and in poorly drained ground.

Multiplication. The species has a great capacity for putting out new shoots and suckers. In order to ensure good germination, prior to sowing in nurseries or directly on-site, seeds are treated by soaking them either in a 20 percent sulphuric acid mixture or in boiling and then cooled water. The species is also disseminated by domestic and wild animals after consumption of the ripe seedpods. Spacing at planting time varies depending on rainfall: from 10 × 10 where rainfall is low to 5 × 5 m where it is heavy. If *Prosopis juliflora* stands are not monitored and properly managed, the species can easily become invasive, especially in sandy zones where the water table is close to the surface.

Uses. The species is a good source of fodder in the form of both leaves and seedpods. When ground, the seedpods provide a flour for both human and livestock consumption. It provides excellent fuelwood and wood for charcoal, poles, floorboards, carpentry, seating, other rustic furniture and barrels. Bees particularly like its flowers and produce very good honey. It is often used to fix very mobile strip dunes, and in plantations to supply fuelwood, wood for charcoal and construction timber. It is also very useful for hedges and fences. However, if it is very densely planted, it prevents growth of the grassy layer because of competition from its spreading root system and the fact that it prevents enough light from reaching the ground. In traditional medicine, its steeped bark is used as an antiseptic in the treatment of ulcers.

SPECIES USED ON INLAND DUNES

Panicum turgidum Forsskal

M. OULD MOHAMED

Panicum turgidum plant

Main source. FAO, 1977.

Other scientific names. -

Common names. Hassaniya: mrokba; English: desert grass.

Family. Graminaceae, Paniceae tribe.

Characteristics. A ramified perennial grass, growing in large clumps, which can reach heights of 1 to 2 m.

Distribution. From Mauritania and northern Senegal to the Sudan and Ethiopia, northern Africa, Libya, Egypt, Iraq, Iran, Pakistan.

Multiplication. Through sowing in nurseries and on-site.

Uses. Like *Aristida pungens*, this fast-growing drought-resistant grass is widely used in the biological fixation of inland dunes in deflation or more stable zones in combination with *Leptadenia pyrotechnica, Aristida pungens* and various acacias. It is used in craftwork by the local inhabitants, and is greatly appreciated by livestock, particularly camels.

SPECIES USED ON INLAND DUNES

Aristida pungens (Desf.) de Winter

M. OULD MOHAMED

Aristida pungens plant

Main source. FAO, 1977.

Other scientific name. *Stipagrostis pungens* Desf.

Common names. Hassaniya: sbot; Arabic: drinn; English: three-awn grass.

Family. Poaceae, Aristideae tribe.

Characteristics. A perennial grass with an elongated, oblique, ramified rhizome. Its roots are very hairy and spread widely. Its culms are often more than 1 m in height.

Distribution. North Africa from Mauritania (mainly in the Adrar *wilaya* at Erch Guible, Tenouchert, N'terguint and Touerga) to Egypt and the Arabian peninsula; also central Asia.

Multiplication. By sowing in nurseries and on-site, and also from root cuttings.

Uses. This grass is widely used in the biological fixation of inland dunes. It spreads easily over very mobile strip dunes and in deflation zones, in association with *Prosopis juliflora*.

SPECIES USED ON COASTAL DUNES

Nitraria retusa Forsskal Asch.

M. OULD MOHAMED

Nitraria retusa bush

Main source. Jaouen, 1988.

Other scientific name. *Nitraria tridentata* Forsskal.

Common names. Hassaniya: aguerzim; Pulaar: guiyel goti; English: salt tree.

Family. Zygophyllaceae.

Characteristics. An evergreen thorny bush reaching a height of 1.5 m, with roughly triangular, alternating, fleshy leaves of varying colours – green, yellow or red. The flowers are yellowish and the fruit red. It often accumulates sand in the form of *nebkas*, which are sometimes large. It is linked to gypseous or saline soil. The species also indicates a fairly shallow water table. Its root system is powerful, with a tap root. However, it is slow growing.

Distribution. Mediterranean in origin, in Mauritania *Nitraria retusa* is confined to coastal zones where the water table has become brackish. Thus it flourishes from Cap Blanc to the lower delta of the Senegal river. It is also found in Zemmour *wilaya*.

Multiplication. From seeds in nurseries and in the natural environment. It has a good germination capacity.

Uses. The species is much grazed by camels. Its fruit, which is watery and slightly sweet, is edible. It is used for the biological fixation of coastal dunes and the regeneration of saline grazing land.

SPECIES USED ON COASTAL DUNES

Tamarix aphylla

M. OULD MOHAMED

Tamarix aphylla tree

Main source. Jaouen, 1988.

Other scientific names. -

Common names. Hassaniya: tharfa; Wolof: mburndu, ngedj; French: tamarix; English: tamarisk.

Family. Tamaricaceae.

Characteristics. Its habit is arborescent. The young branches are greyish green with a filamentous aspect and are often dust-covered because the leaves excrete mineral salts absorbed by the roots and then trap dust suspended in the air. It forms adventitious roots on its trunk and sand-covered branches. It is fast growing, especially when young.

Distribution. In Mauritania, tamarisk is found mainly along the sea coast between Rosso and Nouadhibou. It needs a great deal of water, but does tolerate high salinity – which is why it is found near *sebkhas* (salty swampland at the bottom of depressions), coastal dunes and brackish wadis. It is often found in urban parks.

Multiplication. It is regenerated mainly through cuttings in nurseries (with a height of 15 cm) or directly on dune soil (with heights of 140 cm on the tops of dunes, 120 cm on the sides and 80 cm in depressions). It is also multiplied through suckers, by covering down-curving stalks with damp sand.

Uses. Species used to fix sand and also to protect against sand-bearing winds. Its wood is a mediocre fuel, but can be used as construction timber (poles). Thanks to its capacity for vegetative regeneration, it can be coppiced with a three- to four-year cycle. Livestock tend not to graze tamarisk. Its fruit seems effective as an infusion against colds.

Annex 2

Administrative supervision and project management charts

The 10 tables in this annex are taken from the report "Bilan général des réalisations de la campagne 2007 et synthèse des activités 2000-2007", undertaken by the Support for the Rehabilitation and Extension of the Nouakchott Green Belt Project (FAO, 2008). They serve as a model, but clearly may be improved upon by project leaders.

TABLE 1
Timetable of work

Objectives and activities	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Leaders
Maintenance and renewal of already established tree cover												
A.1 Review and evaluation of existing plantations												100% completed during the season ….
A.2 Establishment of a simple management plan												
2.1 Intervention zone (location)												
Silvicultural treatment and harvesting of plant matter for mechanical stabilization		xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		National coordinator (supervision) and works coordinator
Ongoing training of staff		xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		Forestry experts and harvesting staff
A.3 Field activities												
3.1 Plant nursery (location)												
Supply of new substratum		xx										National coordinator (supervision)
Seed acquisition mission		x										Works coordinator
General infrastructure, beds to store pouches and bare roots, substratum, filling pouches and bare-root raised beds		xxxx										Nursery worker, labourers and guard
Sowing for production of …. seedlings			xxxx	xxxx								
Daily maintenance: watering, root pruning, etc., guarding			xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx			
Ongoing training of staff		xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx			
3.2 Village nursery (location)												
General infrastructure, beds to store pouches, supply of substratum, filling of pouches, sowing, production of …. seedlings				xxxx	xxxx	xxxx						Authorities, community, technical support and hand tools organized by the project
Daily maintenance: watering, root pruning, etc., guarding				xxxx	xxxx	xxxx	xxxx	xxxx	xxxx			Community, technical support and hand tools organized by the project
Guidance and training of the community	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	Technical support and hand tools organized by the project
3.3 Mechanical stabilization and biological fixation of dunes												
3.3.1. Inland dune intervention zone (location)												
Definition of area, topographical survey and mapping	xx											National coordinator (supervision), surveyor and cartographer
Cutting and transport of plant matter and installation of fences and wattling linear metres		xxxx	xxxx	xxxx	xxxx	xxxx			xxxx	xxxx		Works coordinator with guidance from forestry expert
Planting seedlings, watering if necessary, direct sowing							xxxx	xxxx				Workers with guidance from forestry expert
Ongoing training of field staff		xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		Team leaders, field staff
Guarding	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	Guards
3.3.2. Inland dune intervention zone (location)												
Completion of internal wattling … linear metres		xxxx	xxxx									idem 3.3.1.
Restocking seedlings, direct sowing							xxxx	xxxx				
3.3.3. Whole intervention zone (location)												
Guarding	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	Guards

(continues)

TABLE 1 (continued)

Objectives and activities	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Leaders
3.3.4. Village intervention zone participatory approach (location)												
Cutting and transport of plant matter, installation of wattling and reinforcement of boundary fence …. linear metres				xxxx								Community, technical support and hand tools organized by the project
Planting and restocking seedlings, watering, if necessary, within the intervention zone							xxxx	xxxx				Community, technical support and hand tools organized by the project
Guidance and training of the community	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	Team leaders, field staff
Guarding	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	Guards
Trials of coastal dune fixation techniques												
A.1 Production of halophytic species												
Plant nursery (location): production of seedlings, monitoring		xxxx	xxxx	xxxx	xxxx	xxxx						See 3.1. Plant nursery
A.2 Coastal dune intervention zone												
Strengthening and maintenance of existing infrastructure, mainly of seafront fencing linear metres						xxxx						National coordinator, works coordinator, forestry expert, field staff
Restocking seedlings, watering if necessary							xxxx	xxxx				Guard, national NGO
Guarding	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	Guards
Project management activities												
A.1 Timetable of work and annual budget ….	xxx	x										International consultant, national coordinator
A.2 Monthly budget, annual balance sheet (expenditure, balance)	x	x	x	x	x	x	x	x	x	x	x	National coordinator, administration
A.3 Monthly compilation of climatic data, work progress records, staff attendance sheets, salaries, etc.	x	x	x	x	x	x	x	x	x	x	x	National coordinator, works coordinator, meteorological service
A.4 Programme and project management monitoring missions	xxx	x				xx				xx	xx	International consultant, national coordinator
A.5 Six-monthly reports on project progress					xx						xx	National coordinator, works coordinator
A.6 Annual financial report, wrap-up report and project completion report										xx	xx	National coordinator, works coordinator and international consultant
A.7 Drafting national-level project document						xxxx						Consultants, stakeholders
A.8 Leaflet, poster on project goals and achievements								xxxx				Project, NGO, others

TABLE 2
Contribution of the donor government

Code	Item	Staff	Budget (US$)	Remarks
....	**1. Administrative service staff salaries**			Financial year
	Drivers	33 person-months	11 910	Salaries
	Drivers		300	Medical examination expenses
	Subtotal		**12 210**	
....	**2. Consultants**			
	International consultant	10 weeks	11 250	Period to be determined
	National consultant	12 person-months	18 000	National project coordinator's salary
	National consultant	12 person-months	12 000	Works coordinator's salary
	National consultants		200	Medical examination expenses
	Subtotal		**41 450**	
....	**3. Contracts**			
	Topographic survey, mapping, miscellaneous		1 000	Area ....
	Leaflet, photos, film, support workshop		2 000	Coordination with national NGO
	Subtotal		**3 000**	
....	**4. Field staff costs**			From march to end november 2007
	Plant nursery labour	2 694 person-days	9 543	
	Field labour	9 688 person-days	33 348	Mechanical stabilization, harvesting, biological fixation
	Guards	4 877 person-days	16 788	
	National staff allowances		7 317	2 technicians, 3 drivers, 1 guard, others
	Subtotal		**66 996**	
....	**5. Travel**			
	International consultant		18 000	Plane tickets, daily subsistence allowance
	Subtotal		**18 000**	
....	**6. Training**			
	Workshop on project benefits		5 000	2 days, period to be determined
	Subtotal		**5 000**	
....	**7. Permanent equipment**			Local purchase
	1 Power pump for plant nursery		600	
	Subtotal		**600**	
....	**8. Expendable equipment**			Local purchase
	Nursery		2 000	Pouches, seed, watering hoses, miscellaneous
	Stabilization and harvesting, dune fixation		1 500	Two 1000-litre cisterns, gloves, miscellaneous
	Subtotal		**3 500**	
....	**9. Technical support for the project**			
	Technical support mission, others		0	
	Subtotal		**0**	
....	**10. Operating costs**			
	Running and maintaining vehicles		8 691	+ 16 309 over 2006 budget balance; total US$25 000
	Office supplies		500	
	Telephone, fax, e-mail, etc.		2 000	
	Subtotal		**11 191**	+ 16 309 over 2006 budget balance; total US$27 500
	Total 1 to 10		**161 947**	
....	**Agency fees**		**21 053**	13%
	Overall total budget for current financial year		**183 000**	

TABLE 3
Staff requirements and budget estimate

3.1 Plant nursery (location)

	Person-days	No. of days	Total person-days	Person-day salary (UM)	Total salary (UM)	Total salary (US$)
1. Team leader						
01.01 to 30.11	1	334	**334**	1 150	**384 100**	**1 419**
2. Labourers						
01.03 to 31.03	20	26	520	931.5	484 380	1 790
01.04 to 31.07	10	184	1 840	931.5	1 713 960	6 334
Total			**2 360**		**2 198 340**	**8 124**
3. Total (1+2)			**2 694**		**2 582 440**	**9 543**

Estimated average exchange rate: US$1 = 270.61 UM.
Production: 45 000 seedlings.

3.2 Mechanical stabilization, harvesting and biological fixation (location)

	Person-days	No. of days	Total person-days	Person-day salary (UM)	Total salary (UM)	Total salary (US$)
1. Team leader						
01.03 to 31.07*	2	141	282	931.5	262 683	971
01.10 to 30.11*	2	57	114	931.5	106 191	392
01.08 to 30.09**	2	56	112	931.5	104 328	386
Total		**254**	**508**	**931.5**	**473 202**	**1 749**
2. Labourers						
01.03 to 31.03*	30	26	780	931.5	726 570	2 685
01.04 to 31.07*	40	105	4 200	931.5	3 912 300	14 457
01.10 to 30.11*	40	53	2 120	931.5	1 974 780	7 298
01.08 to 30.09**	40	52	2 080	931.5	1 937 520	7 160
Total		**236**	**9 180**	**931.5**	**8 551 170**	**31 600**
3. Total (1+2)						
01.03 to 30.11			**9 688**		**9 024 372**	**33 348**

Estimated average exchange rate: US$1 = 270.61 UM.
* Mechanical stabilization (cutting, transport and installation of plant matter) over …. ha.
+/- …. linear metres per hectare, i.e. a total of …. metres.
* Harvesting in mature stands.
** Biological fixation.

Item	Stabilization	Fixation	Total
No. of person-days	7 496	2 192	**9 688**
US$	25 803	7 546	**33 349**

3.3 Guarding intervention zones

Areas	Person-days	No. of days	Total person-days	Person-day salary (UM)	Total salary (UM)	Total salary (US$)
Inland dunes (location)						
01.01 to 28.02	8	59	472	931.5	439 668	1 625
01.03 to 31.12	12	306	3 672	931.5	3 420 468	12 640
01.07 to 31.12	2	184	368	931.5	342 792	1 267
Total			**4 512**	931.5	**4 202 928**	15 531
Coastal dunes (location)	1	365	**365**	931.5	**339 998**	**1 257**
Total			**4 877**		**4 542 926**	**16 788**

Estimated average exchange rate: US$1 = 270.61 UM.

3.4. Administrative staff

	Person-days	No. of months	Total person-month	Person-month salary (UM)	Total salary (UM)	Total salary (US$)
Drivers 1 & 2	2	11	22	111 000	2 442 000	9 024
Driver 3	1	11	11	71 000	781 000	2 886
Total			**33**		**3 223 000**	**11 910**

Estimated average exchange rate: US$1 = 270.61 UM.

TABLE 4

Annual production of seedlings according to species and production method

Nursery seedling production (location)

No. of seed bed	Production method	No. of seedlings	Species	Date of sowing	Date of germination	No. of seedlings germinated
1	Pouch	1 000	*Panicum turgidum*	15 Apr	20 Apr	965
2	Pouch	1 000	*Panicum turgidum*	15 Apr	20 Apr	972
3	Pouch	1 000	*Acacia raddiana*	16 Apr	22 Apr	930
4	Pouch	1 000	*Acacia raddiana*	16 Apr	23 Apr	910
5	Pouch	1 000	*Acacia raddiana*	16 Apr	23 Apr	926
6	Pouch	1 000	*Acacia raddiana*	16 Apr	22 Apr	967
7 etc.	Pouch	1 000	*Acacia senegal*	17 Apr	24 Apr	935
11 etc.	Pouch	1 000	*Aristida pungens*	20 Apr	25 Apr	757
19 etc.	Bare roots		*Prosopis juliflora*	10 May	14 May	960
24 etc.	Pouch	1 000	*Panicum turgidum*	15 Apr	20 Apr	948
29 etc.	Pouch	1 000	*Prosopis juliflora*	10 May	13 May	984
41 etc.	Pouch	1 000	*Leptadenia pyrotechnica*	18 Apr	25 Apr	783
47 etc.	Pouch	1 000	*Aristida pungens*	20 Apr	26 Apr	856
50	Pouch	1 000	*Acacia senegal*	17 Apr	24 Apr	944
51	Pouch	1 000	*Acacia senegal*	17 Apr	25 Apr	928
52*	Cutting	800	*Tamarix aphylla*	Jun		500

* Last bed.

Total production for the season …. 44 250.

Acacia raddiana: 3 500 seedlings, polyethylene pouch, 8%.
Acacia senegal: 5 300 seedlings, polyethylene pouch, 12%.
Prosopis juliflora: 16 800 seedlings, polyethylene pouch, 38%.
Prosopis juliflora: 2 300 seedlings, bare roots, 5%.
Aristida pungens: 7 150 seedlings, polyethylene pouch, 16%.
Leptadenia pyrotechnica: 3 700 seedlings, polyethylene pouch, 9%.
Panicum turgidum: 4 950 seedlings, polyethylene pouch, 11%.
Tamarix aphylla: 500 seedlings, cutting in pouch, 1%.

TABLE 5

Number of person-days and progress of mechanical stabilization work (location)

Month	Boundary		Counter-dunes		Wattling		Total		Maintenance	
	Person-day	Linear m	Person-day	Linear m	Person-day	Linear m	Person-day	Linear m	Person-day	Linear m
January										
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumulative subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
February										
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumulative subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
March										
01 to 02	0	0	0	0	0	0	0	0	0	0
04 to 09	65	378	0	0	0	0	65	378	0	0
11 to 16	71	461	0	0	0	0	71	461	0	0
18 to 23	92	365	0	0	0	0	92	365	0	0
25 to 30	60	297	0	0	0	0	60	297	0	0
Subtotal	**288**	**1 501**	**0**	**0**	**0**	**0**	**288**	**1 501**	**0**	**0**
Cumulative subtotal	**288**	**1 501**	**0**	**0**	**0**	**0**	**288**	**1 501**	**0**	**0**
April										
01 to 06	80	517	0	0	0	0	80	517	0	0
08 to 13	96	655	0	0	0	0	96	655	0	0
15 to 20	88	545	0	0	0	0	88	545	0	0
22 to 27	114	576	0	0	0	0	114	576	0	0
29 to 30	38	183	0	0	0	0	38	183	0	0
Subtotal	**416**	**2 476**	**0**	**0**	**0**	**0**	**416**	**2 476**	**0**	**0**
Cumulative subtotal	**704**	**3 977**	**0**	**0**	**0**	**0**	**704**	**3 977**	**0**	**0**
May										
01 to 04	51	293	0	0	0	0	51	293	0	0
06 to 11	115	485	0	0	0	0	115	485	0	0
13 to 18	112	508	0	0	0	0	112	508	0	0
20 to 25	0	0	190	1 223	0	0	190	1 223	0	0
27 to 31	0	0	190	1 194	0	0	190	1 194	0	0
Subtotal	**278**	**1 286**	**380**	**2 417**	**0**	**0**	**658**	**3 703**	**0**	**0**
Cumulative subtotal	**982**	**5 263**	**380**	**2 417**	**0**	**0**	**1 362**	**7 680**	**0**	**0**
June										
01	0	0	0	0	0	0	0	0	0	0
03 to 08	0	0	203	1 317	0	0	203	1 317	0	0
10 to 15	0	0	224	1 336	0	0	224	1 336	0	0
17 to 22	0	0	185	932	0	0	185	932	0	0
24 to 29	0	0	230	1 409	0	0	230	1 409	0	0
Subtotal	**0**	**0**	**842**	**4 994**	**0**	**0**	**842**	**4 994**	**0**	**0**
Cumulative subtotal	**982**	**5 263**	**1 222**	**7 411**	**0**	**0**	**2 204**	**12 674**	**0**	**0**
July										
01 to 06	0	0	79	590	149	917	228	1 507	0	0
08 to 13	0	0	0	0	231	1.239	231	1 239	0	0
15 to 20	0	0	0	0	235	1.695	235	1 695	0	0
22 to 27	0	0	0	0	232	1.490	232	1 490	0	0
29 to 31	0	0	0	0	117	871	117	871	0	0
Subtotal	**0**	**0**	**79**	**590**	**964**	**6 212**	**1 043**	**6 802**	**0**	**0**
Cumulative subtotal	**982**	**5 263**	**1 301**	**8 001**	**964**	**6 212**	**3 247**	**19 476**	**0**	**0**
August										
01 to 03	0	0	0	0	58	275	58	275	0	0
05 to 10*	0	0	0	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**58**	**275**	**58**	**275**	**0**	**0**
Cumulative subtotal	**982**	**5 263**	**1 301**	**8 001**	**1 022**	**6 487**	**3 305**	**19 751**	**0**	**0**

(continues)

TABLE 5 (continued)

Month	Boundary		Counter-dunes		Wattling		Total		Maintenance	
	Person-day	Linear m	Person-day	Linear m	Person-day	Linear m	Person-day	Linear m	Person-day	Linear m
Sept*										
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumulative subtotal	**982**	**5 263**	**1 301**	**8001**	**1 022**	**6 487**	**3 305**	**19 751**	**0**	**0**
October										
01 to 05*	0	0	0	0	0	0	0	0	0	0
07 to 12	39	205	105	770	60	391	204	1 366	0	0
14 to 19	20	100	72	590	147	840	239	1 530	0	0
21 to 26	0	0	32	260	163	1 238	195	1 498	0	0
28 to 31	0	0	0	0	117	870	117	870	0	0
Subtotal	**59**	**305**	**209**	**1 620**	**487**	**3 339**	**755**	**5 264**	**0**	**0**
Cumulative subtotal	**1 041**	**5 568**	**1 510**	**9 621**	**1 509**	**9 826**	**4 060**	**25 015**	**0**	**0**
November										
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumulative subtotal	**1 041**	**5 568**	**1 510**	**9 621**	**1 509**	**9 826**	**4 060**	**25 015**	**0**	**0**
December										
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumulative subtotal	**1 041**	**5 568**	**1 510**	**9 621**	**1 509**	**9 826**	**4 060**	**25 015**	**0**	**0**
Overall total	**1 041**	**5 568**	**1 510**	**9 621**	**1 509**	**9 826**	**4 060**	**25 015**	**0**	**0**
Average/person/day		5.3		6.4		6.5		6.2		0.0

* Planting season.

TABLE 6

Balance sheet for the planting and restocking season

6.1 Planting area …. (…. ha)

Date	*Acacia raddiana* Pouch	*Acacia senegal* Pouch	*Leptadenia pyrotechnica* Pouch	*Prosopis juliflora*		*Aristida pungens* Pouch	*Panicum turgidum* Pouch	Total		No. of workers
				Pouch	Bare roots			Pouch	Bare roots	
1 Aug*	0	0	0	0	0	0	0	0	0	20
2 Aug	50	50	0	0	0	20	20	140	0	39
5 Aug	200	200	0	200	0	200	0	800	0	41
etc. until										
4 Oct	0	0	220	190	0	0	0	410	0	39
5 Oct**	0	10	210	0	0	0	0	220	0	40
Total 1	**3 020**	**2 040**	**4 365**	**8 795**	**0**	**5 700**	**3 535**	**27 455**	**0**	**2 187**

* Start of season.

** End of season.

6.2 Restocking area ….

Date	*Acacia raddiana* Pouch	*Acacia senegal* Pouch	*Leptadenia pyrotechnica* Pouch	*Prosopis juliflora*		*Aristida pungens* Pouch	*Panicum turgidum* Pouch	Total		No. of workers
				Pouch	Bare roots			Pouch	Bare roots	
28 Sept	0	0	0	200	0	0	0	200	0	42
30 Sept	375	125	0	0	0	0	0	500	0	41
Total 2	**375**	**125**	**0**	**200**	**0**	**0**	**0**	**700**	**0**	**83**

6.3 Overall performance: planting and restocking season ….

Status	*Acacia raddiana* Pouch	*Acacia senegal* Pouch	*Leptadenia pyrotechnica* Pouch	*Prosopis juliflora*		*Aristida pungens* Pouch	*Panicum turgidum* Pouch	Total		No. of workers
				Pouch	Bare roots			Pouch	Bare roots	
Total 1	3 020	2 040	4 365	8 795	0	5 700	3 535	27 455*	0	2 187**
Total 2	375	125	0	200	0	0	0	700	0	83
Total	**3 395**	**2 165**	**4 365**	**8 995**	**0**	**5 700**	**3 535**	**28 155**	**0**	**2 270**
Overall total									**28 155**	

* i.e. 177 seedlings per hectare (total …. ha).

** i.e. 12.5 seedlings per person-day.

TABLE 7
Workers' attendance and salary sheets

7.1 Plant nursery

Location: ....
Nature of work: **General maintenance**
Year, month .... 1st to 15th

Code: **....**
* = Team leader
H = Holiday

Name of worker / **Date**	**1**	**2**	**3**	**4**	**5**	**6**	**H 7**	**8**	**9**	**10**	**11**	**12**	**13**	**H 14**	**15**
1. A *	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2. B	1	1	1	1	1	1		1	1	1	1	1	1		1
3. C	1	1	1	1	1	1		1	1	1	1	1	1		1
4. D	1	1	1	1	1	1		1	1	1	1	1	1		1
5. E	1	1	1	1	1	1		1	1	1	1	1	1		1
6. F	1	1	1	1	1	1		1	1	1	1	1	1		1
7. G	1	1	1	1	1	1		1	1	1	1	1	1		1
8. H	1	1	1	1	1	1		1	1	1	1	1	1		1
9. I	1	1	1	1	1	1		1		1	1	1	1		1
10. J	1	1	1	1	1	1		1	1	1	1	1	1		1
11. K	1	1	1	1	1	1		1	1	1	1	1	1		1
12. L	1	1	1	1	1	1		1	1	1	1	1	1		1
13. M	1	1	1	1	1	1		1	1	1	1	1	1		1
14. N	1	1	1	1	1	1		1	1	1	1	1	1		1
Total person-days	14	14	14	14	14	14	1	14	13	14	14	14	14	1	14
Total UM															
Employer's contribution 15%															
Overall total UM															
UM/US$ exchange rate															
Total US$															

Date and signature of Works Coordinator:

Date and signature of Project Coordinator:

7.2 Field team 1

Location: ....
Nature of work: **Mechanical dune stabilization**
Year, month .... 1st to 15th

Code: **....**
* = Leader of team 1
H = Holiday

Name of worker / **Date**	**1**	**2**	**3**	**4**	**5**	**6**	**H 7**	**8**	**9**	**10**	**11**	**12**	**13**	**H 14**	**15**
1. A*	2	1	1	1	1	1		1	1	1	1	1	1		1
2. B	1	1	1	1	1	1		1	1	1	1	1	1		1
3. C	1	1	1	1	1	1		1	1	1	1	1	1		1
4. D	1	1	1	1	1	1		1	1	1	1	1	1		1
5. E	1	1	1	1	1	1		1	1	1	1	1	1		1
etc. up to 20. T															
20. T	1	1	1	1	1	1		1	1	1	1	1	1		1
Total person-days	19	20	20	20	20	20	0	18	20	20	20	20	20	0	19
Total UM															
Employer's contribution 15%															
Overall total UM															
UM/US$ exchange rate															
Total US$															

Date and signature of Works Coordinator:

Date and signature of Project Coordinator:

Total days present	Daily salary (UM)	Gross salary (UM)	Leave 1 month/yr	Salary 15 days (UM)	Social Security Fund 1%	Net salary (UM)	Worker's signature
15	1 000	15 000	1 250	16 250	163	16 088	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
12	810	9 720	810	10 530	105	10 425	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
183							
				163 670	**1 637**	**162 033**	
				24 551	**26 187**		
				188 221		**188 221**	
				260.00			
				723.93			

Total days present	Daily salary (UM)	Gross salary (UM)	Leave 1 month/yr	Salary 15 days (UM)	Social Security Fund 1%	Net salary (UM)	Worker's signature
14	810	11 340	945	12 285	123	12 162	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
13	810	10 530	878	11 408	114	11 293	
256							
				224 640	**2 246**	**222 394**	
				33 696	**35 942**		
				258 336		**258 336**	
				260.00			
				993.60			

(continues)

TABLE 7 (continued)

7.3 Field team 2

Location: ....
Nature of work: **Mechanical dune stabilization**
Year, month .... 1st to 15th

Code: ....
* = Leader of team 2
H = Holiday

Name of worker / **Date**	**1**	**2**	**3**	**4**	**5**	**6**	**H 7**	**8**	**9**	**10**	**11**	**12**	**13**	**H 14**	**15**
1. A*	2	1	1	1	1	1		1	1	1	1	1	1		1
etc. up to 19.S															
19.S	1	1	1	1	1	1		1	1	1	1	1	1		1
Total person-days	16	19	19	19	19	19	0	18	19	19	19	19	19	0	19
Total UM															
Employer's contribution 15%															
Overall total UM															
UM/US$ exchange rate															
Total US$															

Date and signature of Works Coordinator:

Date and signature of Project Coordinator:

7.4 Field teams 1 and 2

Location: ....
Nature of work: **Biological dune fixation**
Year, month .... 1st to 15th

Code: **....**
* = leader of team 1 (idem for leader of team 2)
H = Holiday

Note: No planting during this period

7.5 Guards

Location: ....
Nature of work: **Guarding**
2007: 1-15 July

H = Holiday

Name of worker / **Date**	**1**	**2**	**3**	**4**	**5**	**6**	**H 7**	**8**	**9**	**10**	**11**	**12**	**13**	**H 14**	**15**
1. A (Toujounine)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
etc. up to 11 K															
11. K (Toujounine)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12. L (coastal dune)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total person-days	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total UM															
Employer's contribution 15%															
Overall total UM															
UM/US$ exchange rate															
Total US$															

Date and signature of Works Coordinator:

Date and signature of Project Coordinator:

Total days present	Daily salary (UM)	Gross salary (UM)	Leave 1 month/yr	Salary 15 days (UM)	Social Security Fund 1%	Net salary (UM)	Worker's signature
14	810	11 340	945	12 285	123	12 162	
13	810	10 530	878	11 408	114	11 293	
243							
				213 233	**2 132**	**211 100**	
				31 985	**34 117**		
				245 217		**245 217**	
				260.00			
				943.14			

Total days present	Daily salary (UM)	Gross salary (UM)	Leave 1 month/yr	Salary 15 days (UM)	Social Security Fund 1%	Net salary (UM)	Worker's signature
15	810	12 150	1 013	13 163	132	13 031	
15	810	12 150	1 013	13 163	132	13 031	
15	810	12 150	1 013	13 163	132	13 031	
180					0	0	
				157 950	**1 580**	**156 371**	
				23 693	**25 272**		
				181 643		**181 643**	
				260.00			
				698.63			

(continues)

TABLE 7 (continued)

7.6 Summary of expenditure on staff

Year ….. 1–15 July

Nature of work	No. of person-days	Cost (UM)	Exchange rate	Cost (US$)
Plant nursery	183	188 221	260	723.93
	0	0	260	0.00
	0	0	260	0.00
Subtotal	**183**	**188 221**	260	**723.93**
Mechanical stabilization	256	258 336	260	993.60
	243	245 217	260	943.14
	0	0	260	0.00
Subtotal	**499**	**503 553**	260	**1 936.74**
Biological fixation	0	0	260	0.00
(planting and restocking)	0	0	260	0.00
	0	0	260	0.00
Subtotal	**0**	**0**	260	**0.00**
Guarding				
Toujounine (11)	165	166 506	260	640.41
Coastal dunes (1)	15	15 137	260	58.22
Subtotal	**180**	**181 643**	260	**698.63**
Total*	**862**	**873 417**	260	**3 359.30**

* These figures are found in Table 8 for the period 1–15 July….

TABLE 8

Number of person-days and monthly costs for nursery and fieldwork

Real staff costs in US$ (nursery, mechanical stabilization and forest harvesting, biological fixation, guarding)

Jan–Dec ….	Nursery		Mechanical stabilization* and forest harvesting		Biological fixation**		Guarding***		Total	
	Person-days	Cost (US$)	Person-days	Cost (US$)	Person-days	Cost (US$)	Person-days	Cost (US$)	Person-days	Cost (US$)
01-15 January	15	69.06	0	0.00	0	0.00	135	503.43	150	572.49
16-31 January	16	71.33	0	0.00	0	0.00	128	478.81	144	550.14
	31	**140.39**	**0**	**0.00**	**0**	**0.00**	**263**	**982.24**	**294**	**1 122.63**
01-15 February	15	68.95	0	0.00	0	0.00	120	446.81	135	515.76
16-28 February	13	59.75	0	0.00	0	0.00	104	387.24	117	446.99
	28	**128.70**	**0**	**0.00**	**0**	**0.00**	**224**	**834.05**	**252**	**962.75**
01-15 March	225	851.09	270	1 039.11	0	0.00	120	446.93	615	2 337.13
16-31 March	278	1.049.36	365	1 359.41	0	0.00	128	476.72	771	2 885.49
	503	**1 900.45**	**635**	**2 398.52**	**0**	**0**	**248**	**923.65**	**1 386**	**5 222.62**
01-15 April	247	931.11	410	1 526.72	0	0.00	105	390.99	762	2 848.82
16-30 April	182	690.82	505	1 880.47	0	0.00	105	390.99	792	2 962.28
	429	**1 621.93**	**915**	**3 407.19**	**0**	**0.00**	**210**	**781.98**	**1 554**	**5 811.10**
01-15 May	183	694.54	481	1 791.10	0	0.00	145	539.94	809	3 025.58
16-31 May	198	777.07	535	2 060.62	0	0.00	176	677.88	909	3 515.57
	381	**1 471.61**	**1 016**	**3 851.72**	**0**	**0.00**	**321**	**1 217.82**	**1 718**	**6 541.15**
01-15 June	243	949.50	427	1 644.64	0	0.00	150	577.74	820	3 171.88
16-30 June	171	673.50	466	1 808.66	0	0.00	237	919.86	874	3 402.02
	414	**1 623.00**	**893**	**3 453.30**	**0**	**0.00**	**387**	**1 497.60**	**1.694**	**6 573.90**
01-15 July	183	723.93	499	1 936.74	0	0.00	180	698.63	862	3 359.30
16-31 July	196	775.29	548	2 126.93	0	0.00	192	745.20	936	3 647.42
	379	**1 499.22**	**1 047**	**4 063.67**	**0**	**0.00**	**372**	**1 443.83**	**1 798**	**7 006.72**
01-15 August	184	734.39	0	0.00	520	2 036.50	195	763.69	899	3 534.58
16-31 August	197	786.22	0	0.00	587	2 298.90	208	814.60	992	3 899.72
	381	**1 520.61**	**0**	**0.00**	**1 107**	**4 335.40**	**403**	**1 578.29**	**1 891**	**7 434.30**
01-15 September	169	675.64	0	0.00	495	1 938.59	195	763.69	859	3 377.92
16-30 September	184	734.39	0	0.00	537	2 103.08	195	763.69	916	3 601.16
	353	**1 410.03**	**0**	**0.00**	**1 032**	**4 041.67**	**390**	**1 527.38**	**1 775**	**6 979.08**
01-15 October	184	734.39	327	1 280.65	199	779.35	195	763.69	905	3 558.08
16-31 October	198	790.13	549	2 150.08	0	0.00	208	814.60	955	3 754.81
	382	**1 524.52**	**876**	**3 430.73**	**199**	**779.35**	**403**	**1 578.29**	**1 860**	**7 312.89**
01-15 November	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
16-30 November	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	0	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**
01-15 December	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
16-31 December	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	0	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**
Total staff	**3 281**		**5 382**		**2 338**		**3 221**		**14 222**	
Total staff anticipated	2 694		7 496		2 192		4 877		17 259	
Staff balance	**-587**		**2 114**		**-146**		**1 656**		**3 037**	
Expenditure US$		**12 840.46**		**20 605.13**		**9 156.42**		**12 365.13**		**54 967.14**
Budget US$		9 543.00		25 802.00		7 546.00		16 788.00		59 679.00
Balance US$		**-3 297.46**		**5 197.87**		**-1 610.42**		**4 422.87**		**4 711.86**

* Cutting and transport of plant matter and installation of fences and internal wattling in the intervention zone….

** Planting …. ha, season …., restocking, watering of seedlings if necessary, on-site sowing.

*** …. person-days for inland dunes and …. person-days for coastal dunes.

TABLE 9
Local expenditure in US$ for financial year

Costs of international consultations, national experts, drivers, mission reports and agency fees are not included in this table.

Budget line	Jan	Feb	Mar	Apr	May	Jun	Jul
Exchange rate	**270.61**	**271.02**	**270.95**	**271.00**	**271.00**	**262.00**	**260.00**
01-01	69.06	200.05	1 900.45	931.11	1 385.35	1 726.58	2 172.72
01-02			2 398.51	1 526.72	3 671.57	3 705.26	5 872.33
01-03			870.12	259.77			270.76
01-04	503.43	1 312.87	923.65	390.98	930.93	1 255.63	2 363.68
01-05		1 328.31	664.33		664.21	687.02	1 384.61
Subtotal	572.49	2 841.23	6 757.06	3 108.58	6 652.06	7 374.49	12 064.10
02						575.38	
03-01		2 213.86	3 482.93	242.43	4 347.91	152.67	5 830.77
03-02		90.71	243.63	131.38	144.57	238.85	383.69
03-03			333.25			152.67	207.69
Subtotal	0.00	2 304.57	4 059.81	373.81	4 492.48	544.19	6 422.15
04-01					215.87		743.85
04-02			2 483.85				692.31
04-03			479.79				1 153.85
Subtotal	0.00	0.00	2 963.64	0.00	215.87	0.00	2 590.01
05			627.42				388.46
06			597.89				
07			129.17		147.60		
08					7 458.11		
Total US$	572.49	5 145.80	15 134.99	3 482.39	18 966.12	8 494.06	21 464.72
Cumulative total	572.49	5 718.29	20 853.28	24 335.67	43 301.79	51 795.85	73 260.57

01-01: nursery staff; 01-02: field staff; 01-03: drivers; 01-04: guards; 01-05: staff allowances; 02: local contracts; 03-01: running of vehicles; 03-02: operation of office; 03-03: contingencies; 04-01: office supplies; 04-02: expendable nursery equipment; 04-03: expendable field equipment; 05: computer unit; 06: purchase of non-expendable equipment (local and external); 07: medical examinations of technical staff; 08: national consultant.

***** There was no expenditure in November and December …. .

Aug 257.67	Sep 257.67	Oct 257.67	Nov* 257.72	Dec* 257.72	Total expenditure (US$)	Total available (US$)	Balance (US$)
734.39	1 461.86	2 258.91			12 840.46	**9 543**	-3 297.46
2 036.50	4 237.49	6 313.15			29 761.53	**33 348**	3 586.47
273.21		546.43			2 220.29	**2 104**	-116.29
763.69	1 578.29	2 341.97			12 365.12	**16 788**	4 422.88
	698.57	1 397.14			6 824.19	**7 317**	492.81
3 807.79	7 976.21	12 857.60	0.00	0.00	64 011.59	**69 100**	**5 088.41**
					575.38	**3 000**	**2 424.62**
4 028.02	712.86	7 611.67			28 623.12	**25 000**	-3 623.12
		177.72			1 410.55	**2 000**	589.45
					693.61	**1 500**	806.39
4 028.02	712.86	7 789.39	0.00	0.00	30 727.28	**28 500**	**-2 227.28**
					959.72	**500**	-459.72
					3 176.16	**2 500**	-676.16
					1 633.64	**1 500**	-133.64
0.00	0.00	0.00	0.00	0.00	5 769.52	**4 500**	**-1 269.52**
					1 015.88	**1 500**	**484.12**
					597.89	**600**	**2.11**
					276.77	**300**	**23.23**
					7 458.11	**7 500**	**41.89**
7 835.81	8 689.07	20 646.99	0.00	0.00	110 432.44	115 000.00	4 567.56
81 096.38	89 785.45	110 432.44	110 432.44	110 432.44		**115 000.00**	**4 567.56**

TABLE 10
Requirements for expendable and non-expendable equipment

10.1 Non-expendable equipment and available material acquired during previous seasons

Non-expendable equipment
1 vehicle Toyota Land Cruiser Pick-Up, registration ....
1 vehicle Toyota Land Cruiser Pick-Up, registration ....
1 vehicle Toyota Hilux 2.8 D double cabin, registration ....
1 vehicle Toyota Land Cruiser Pick-Up, registration ....
1 computer Compaq Pentium IV
1 computer HP L1706
1 external hard disk 80 G
1 printer Laserjet Canon LBP 810
Etc.

Expendable equipment (stored)	
200-litre drum, 12 units	Machete, 20 units
Secateurs Felco 8, 8 units	Lopping shears, 3 units
Planting cylinder, 10 units	Bow saw, 765 mm long, 7 units
Wheelbarrow, 36 units	Bow saw, 530 mm long, 7 units
Watering can, 66 units	Blade saw (large model), 30 units
Etc.	

10.2 Local purchase of non-expendable equipment

1 power pump G200 5.0	US$600

10.3 Local purchase of expendable equipment (nursery, dune fixation, forest harvesting)

Item	**Quantity**	**Unit cost (UM)**	**Total**	**Cost (US$)**	**Notes**
Watering hose (m)	150	300	45 000	166	per 50-m roll
Leather gloves (pair)	100	3 000	300 000	1 109	
Cistern 1 000 litres (unit)	2	50 000	100 000	370	
Seed (kg):					
Acacia raddiana	3	6 000	18 000	67	
Acacia senegal	3	9 000	27 000	100	
Prosopis juliflora	8	12 000	96 000	355	
Leptadenia pyrotechnica	8	8 000	64 000	237	
Aristida pungens	8	10 000	80 000	296	
Panicum turgidum	10	8 000	80 000	296	
Nitraria retusa	1	5 000	5 000	18	
Tamarix aphylla (cutting)					to be noted
Colocynthus vulgaris	10	4 000	40 000	148	
Miscellaneous			92 007	340	
Total			**947 007**	**3 500**	Exchange rate: US$1 = 270.61 UM
Total available				3 500	(January ....)

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FAO FORESTRY PAPER

Fighting sand encroachment

Lessons from Mauritania

One of the main challenges of desertification is encroachment of moving sands, which has devastating environmental and socio-economic impacts. It reduces arable land, grazing land and availability of water resources, threatening agricultural productivity and yields and the food security and standard of living of local populations. Other impacts include large-scale migration of people, infrastructure damage and substantial economic losses. Mauritania, as one of the most severely affected countries in sub-Saharan Africa, has accumulated a great deal of experience in combating sand encroachment over the past several decades. This publication synthesizes the lessons learned, particularly in the implementation of a recently concluded and highly successful project for rehabilitation and extension of the Nouakchott Green Belt, carried out by FAO and the Government of Mauritania with support from the Walloon Region of Belgium. It describes sand encroachment processes and control techniques from preliminary studies to nursery methods to dune fixation and protection of reforested areas. Project management and institutional aspects are also addressed, with an emphasis on the use of a participatory approach. Annexes include profiles of local woody and grassy species used in sand dune fixation, and tables used to manage activities and budgets and monitor progress, which can serve as a model for future efforts. These lessons can be adapted to other countries facing similar challenges. The publication will be of interest to technicians, project managers, local communities and indeed all stakeholders engaged in combating desertification.

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